US010364709B2

(12) **United States Patent**
Tanaka et al.

(10) **Patent No.: US 10,364,709 B2**
(45) **Date of Patent: Jul. 30, 2019**

(54) **VARIABLE VALVE MECHANISM, ENGINE, AND AUTOMATIC TWO-WHEELED VEHICLE**

(71) Applicant: **SUZUKI MOTOR CORPORATION**, Hamamatsu-shi, Shizuoka (JP)

(72) Inventors: **Koichi Tanaka**, Hamamatsu (JP); **Kunio Arase**, Hamamatsu (JP)

(73) Assignee: **SUZUKI MOTOR CORPORATION**, Hamamatsu-Shi (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 85 days.

(21) Appl. No.: **15/639,562**

(22) Filed: **Jun. 30, 2017**

(65) **Prior Publication Data**

US 2018/0010487 A1 Jan. 11, 2018

(30) **Foreign Application Priority Data**

Jul. 5, 2016 (JP) 2016-133288

(51) **Int. Cl.**
F01L 1/34 (2006.01)
F01L 1/344 (2006.01)
F01L 1/053 (2006.01)
F01L 1/18 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F01L 1/344*** (2013.01); ***F01L 1/053*** (2013.01); *F01L 1/181* (2013.01); *F01L 1/267* (2013.01); *F01L 2001/0473* (2013.01); *F01L 2001/0475* (2013.01); *F01L 2001/0535* (2013.01); *F01L 2105/00* (2013.01); *F01L 2820/035* (2013.01)

(58) **Field of Classification Search**
CPC F01L 2001/0535; F01L 1/344; F01L 1/34409; F01L 1/34413; F01L 2001/34483; F01L 1/46; F01L 2820/035
USPC 123/90.17, 90.27
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,121,560 A * 6/1938 Duncan F01L 1/34403 123/90.15
4,577,592 A * 3/1986 Bosch F01L 1/344 123/90.15

(Continued)

FOREIGN PATENT DOCUMENTS

CN	1632292 A	6/2005
JP	2011-1882 A	1/2011

OTHER PUBLICATIONS

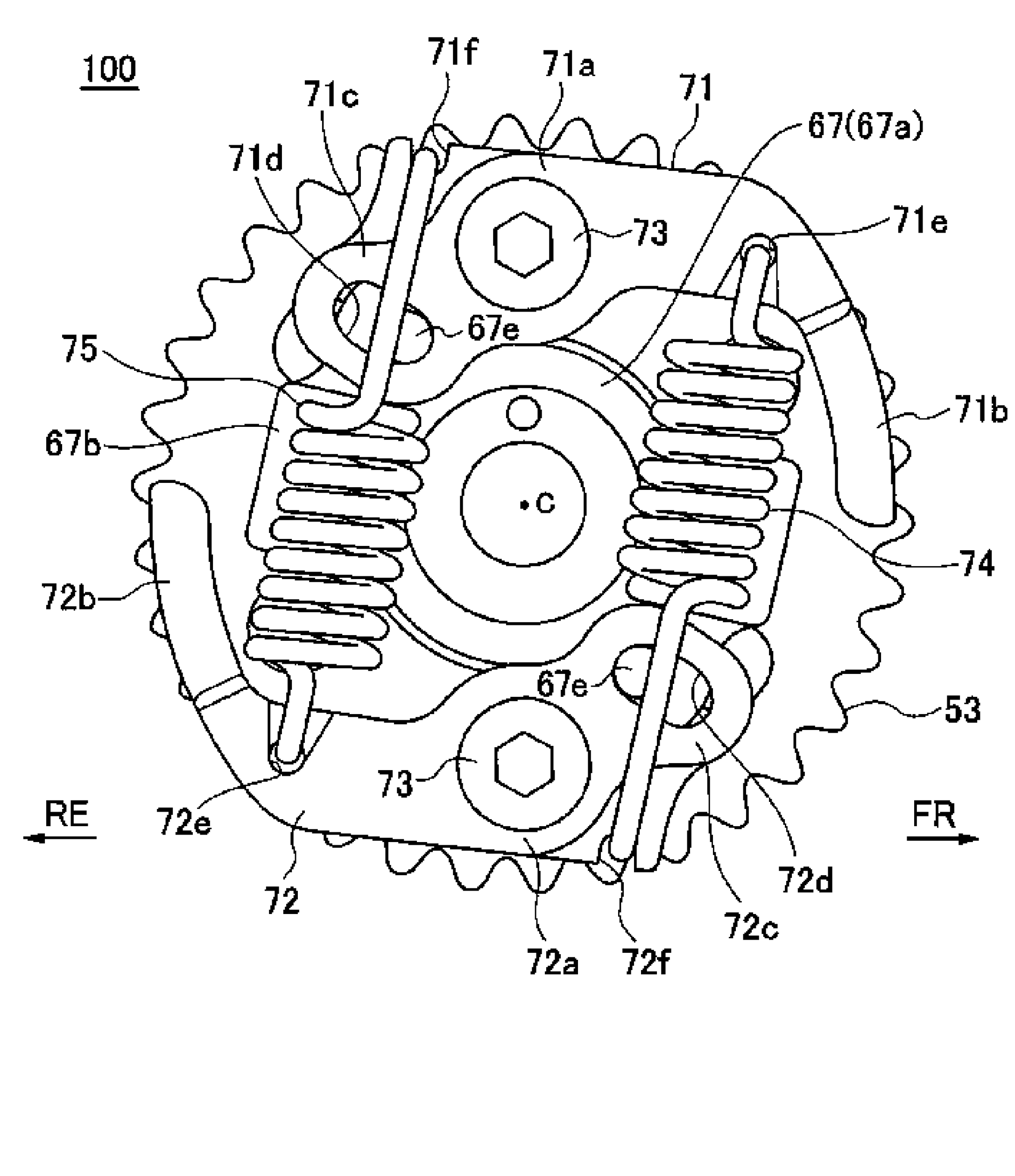
Chinese Office Action dated May 23, 2019, issued to Chinese Application No. 201710533022.8.

Primary Examiner — Jorge L Leon, Jr.
(74) *Attorney, Agent, or Firm* — Stein IP, LLC

(57) **ABSTRACT**

The present invention is capable of more smoothly changing a phase of a cam shaft in a rotation direction. A variable valve mechanism changes an opening/closing timing of an intake valve or an exhaust valve in response to an engine rotation speed. The variable valve mechanism includes: a cam sprocket which rotates in response to a rotation of a crank shaft; an intake cam shaft which is integrated with an intake cam and is provided to be rotatable relatively to the cam sprocket; and a link member that transmits a rotation from the cam sprocket to the intake cam shaft. The link member is supported by the cam sprocket to be swingable and swings in response to a change in rotation speed of the cam sprocket to rotate the intake cam shaft relatively to the cam sprocket.

13 Claims, 11 Drawing Sheets



(51) **Int. Cl.**
F01L 1/26 (2006.01)
F01L 1/047 (2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,708,101	A *	11/1987	Hara	F01L 1/34406 123/90.16
5,179,918	A *	1/1993	Gyurovits	F01L 1/344 123/90.17
6,289,860	B1 *	9/2001	Speckhart	F01L 1/02 123/90.15
2004/0055548	A1 *	3/2004	Williams	F01L 1/022 123/90.15
2009/0240420	A1 *	9/2009	Ishigami	F01L 1/022 701/103
2009/0272348	A1 *	11/2009	Yamamoto	F01L 1/022 123/90.17
2012/0152194	A1 *	6/2012	Arai	F01L 1/146 123/90.15
2012/0279466	A1 *	11/2012	Schober	F01L 1/352 123/90.17

* cited by examiner

FIG. 1

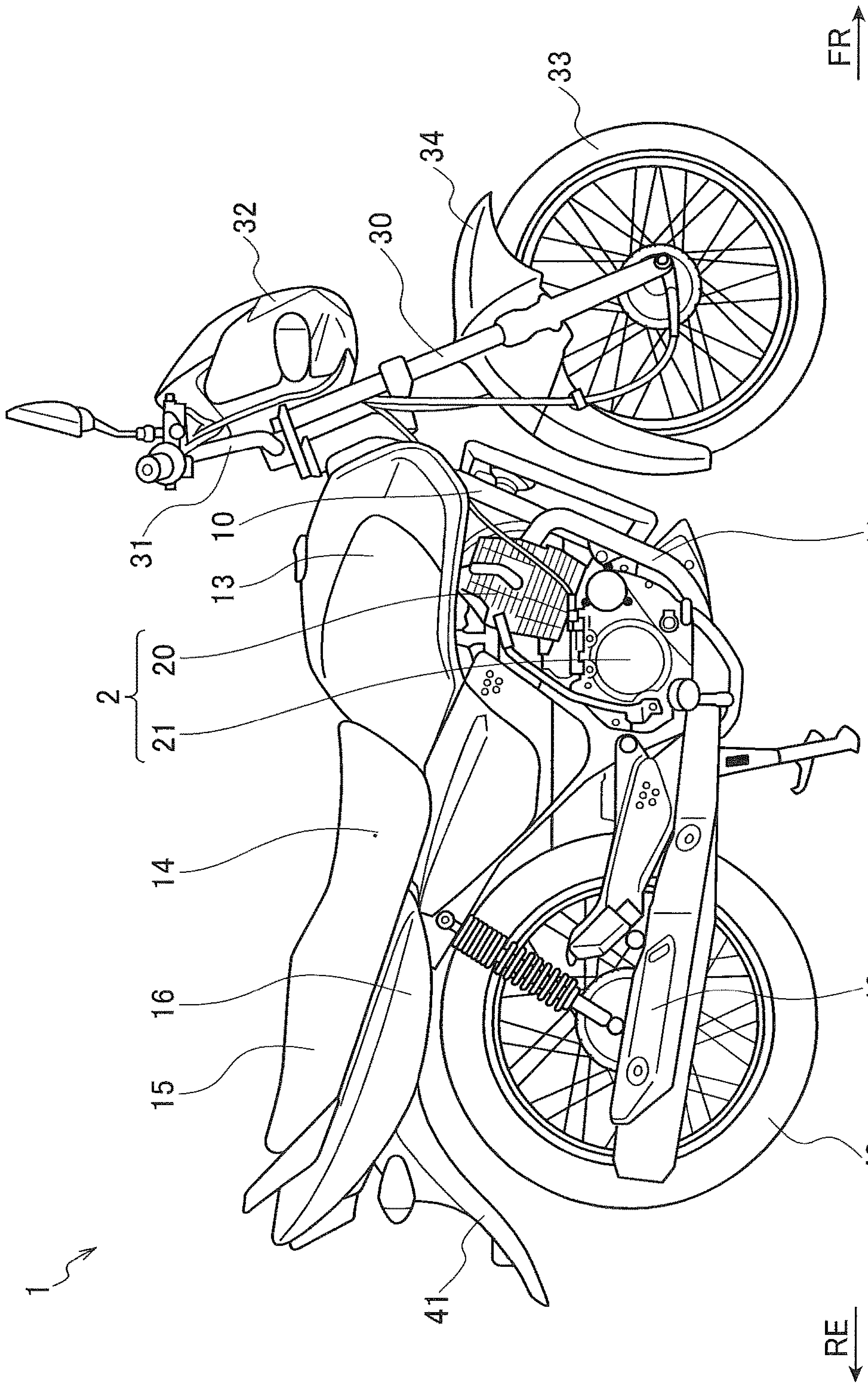


FIG. 2

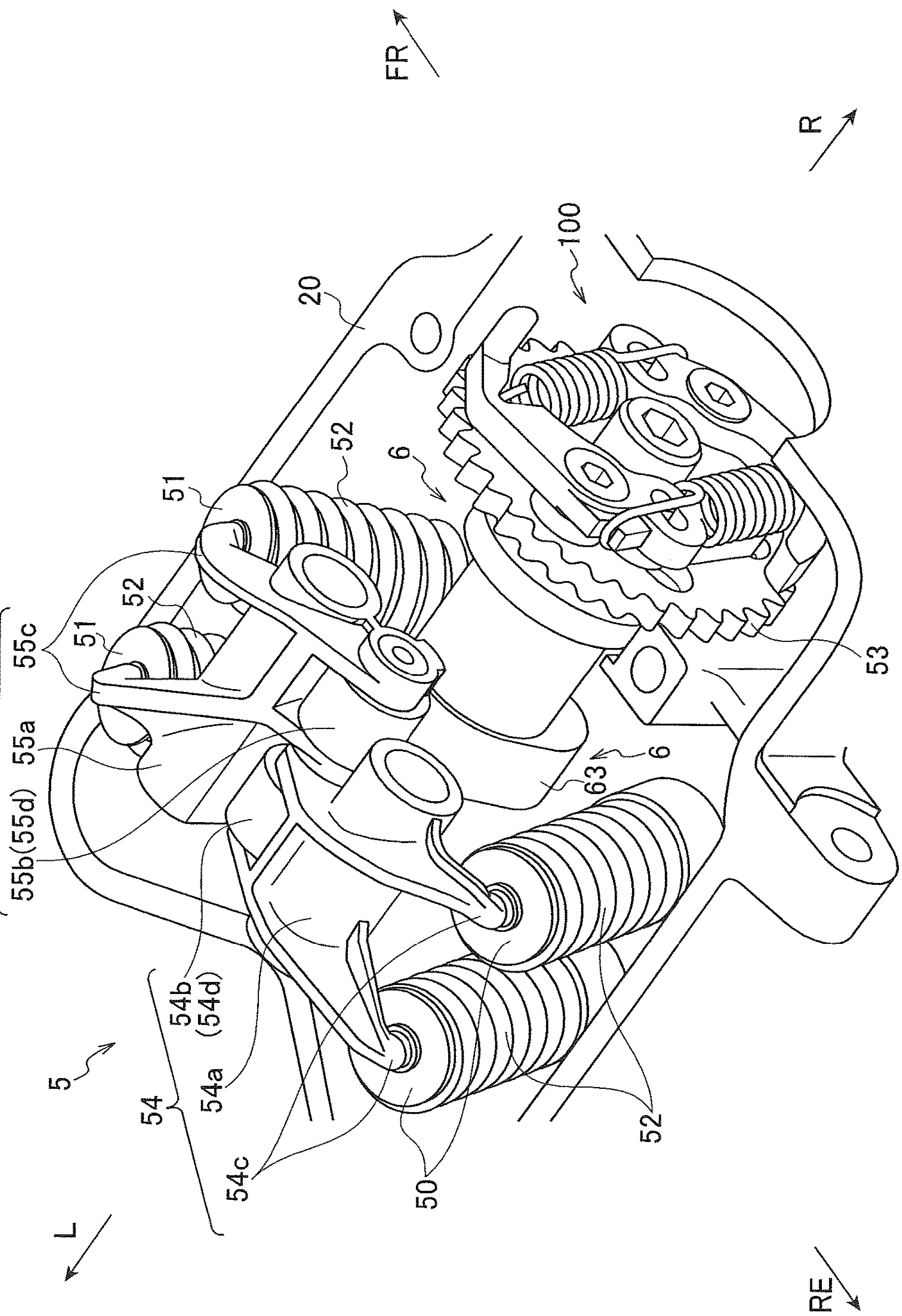

FR
R
100
20
6
52
51
52
55c
51
55
55a
55b(55d)
53
6
63
54b
(54d)
5
54
54a
54c
50
52
L
RE

FIG. 3

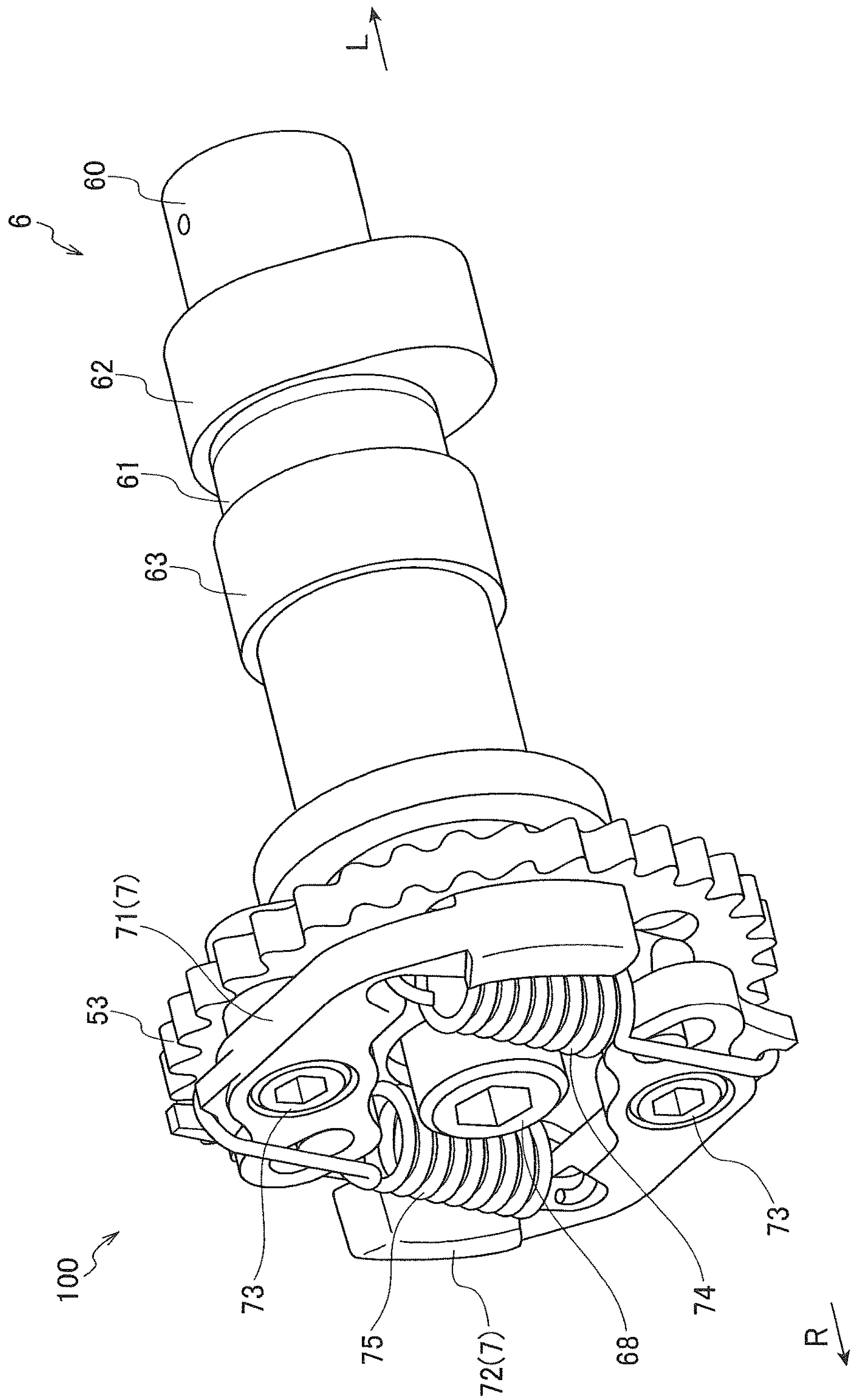


FIG. 4

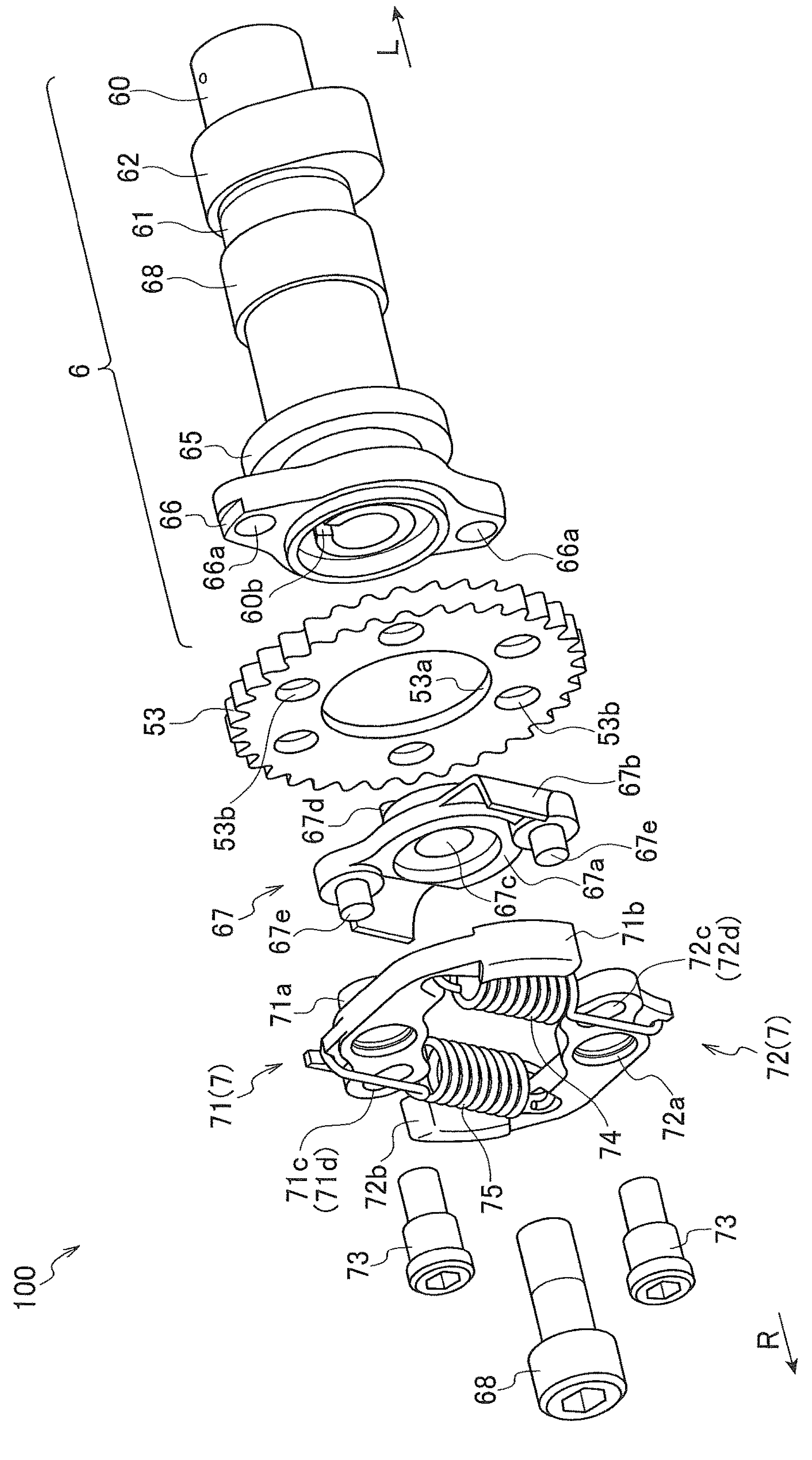

L
60
62
61
68
6
65
66
66a
66a
60b
53
53a
53b
53b
67b
67d
67e
67a
67c
67
67e
71b
72c
(72d)
71a
72(7)
71(7)
74
72a
71c
(71d)
72b
75
73
73
100
68
R

FIG. 5

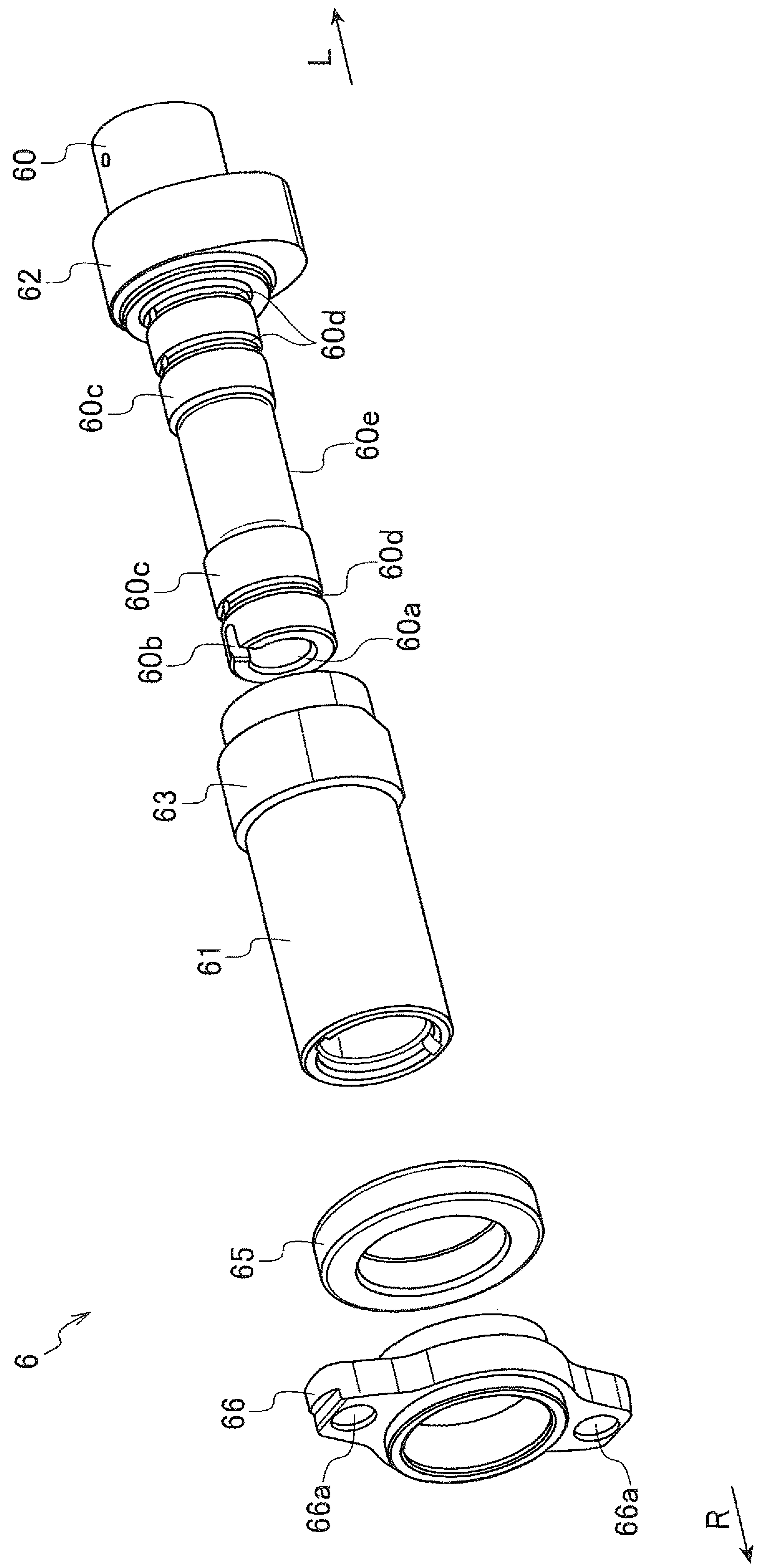


FIG. 6

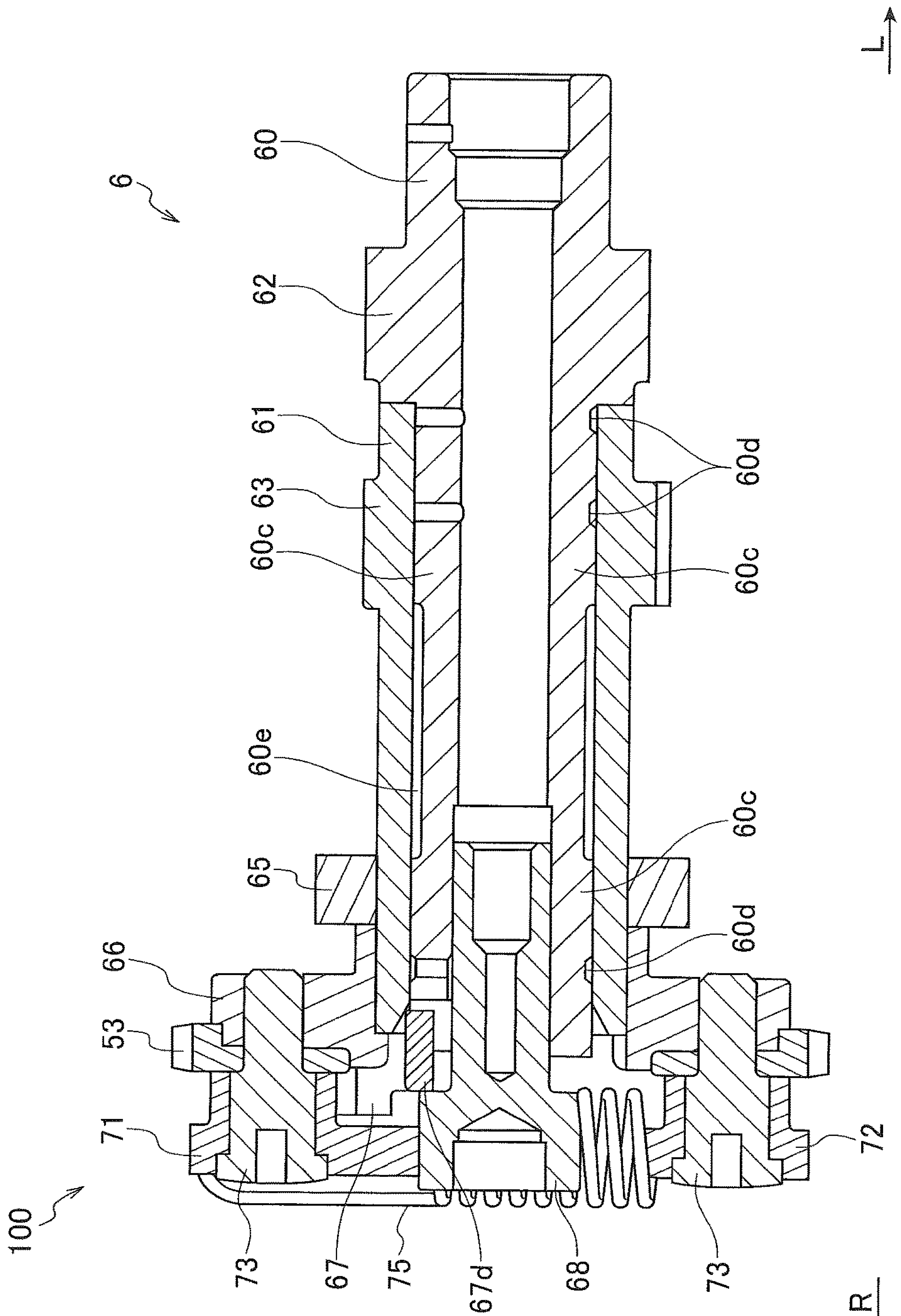

6
60
62
61
63
60c
60e
65
66
53
71
100
73
67
75
67d
68
73
72
60d
60c
60c
60d
L
R

FIG. 7

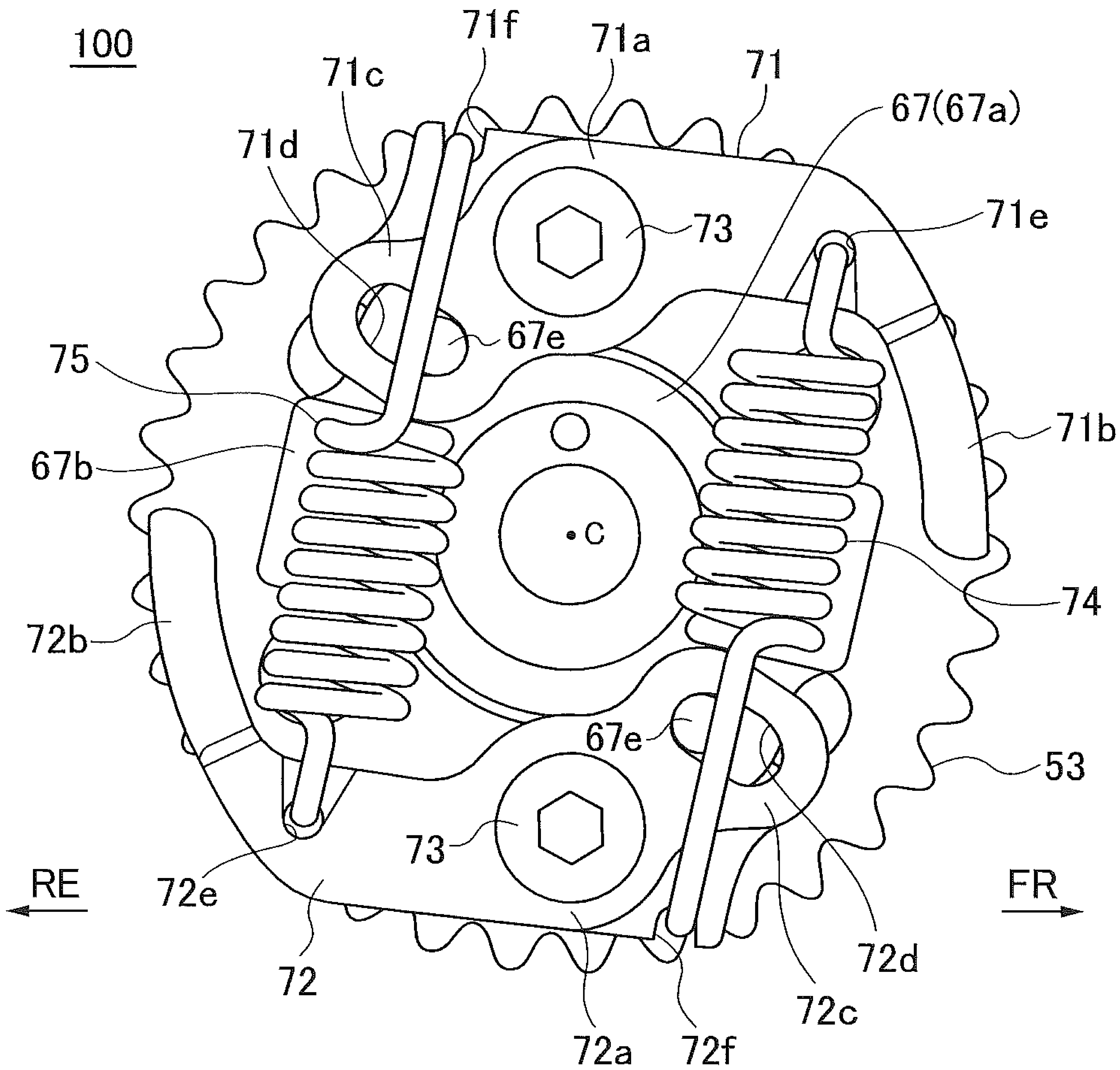

100
71f
71a
71
71c
67(67a)
71d
73
71e
67e
75
71b
67b
C
74
72b
67e
53
73
72e
RE
FR
72d
72
72c
72a
72f

FIG. 8

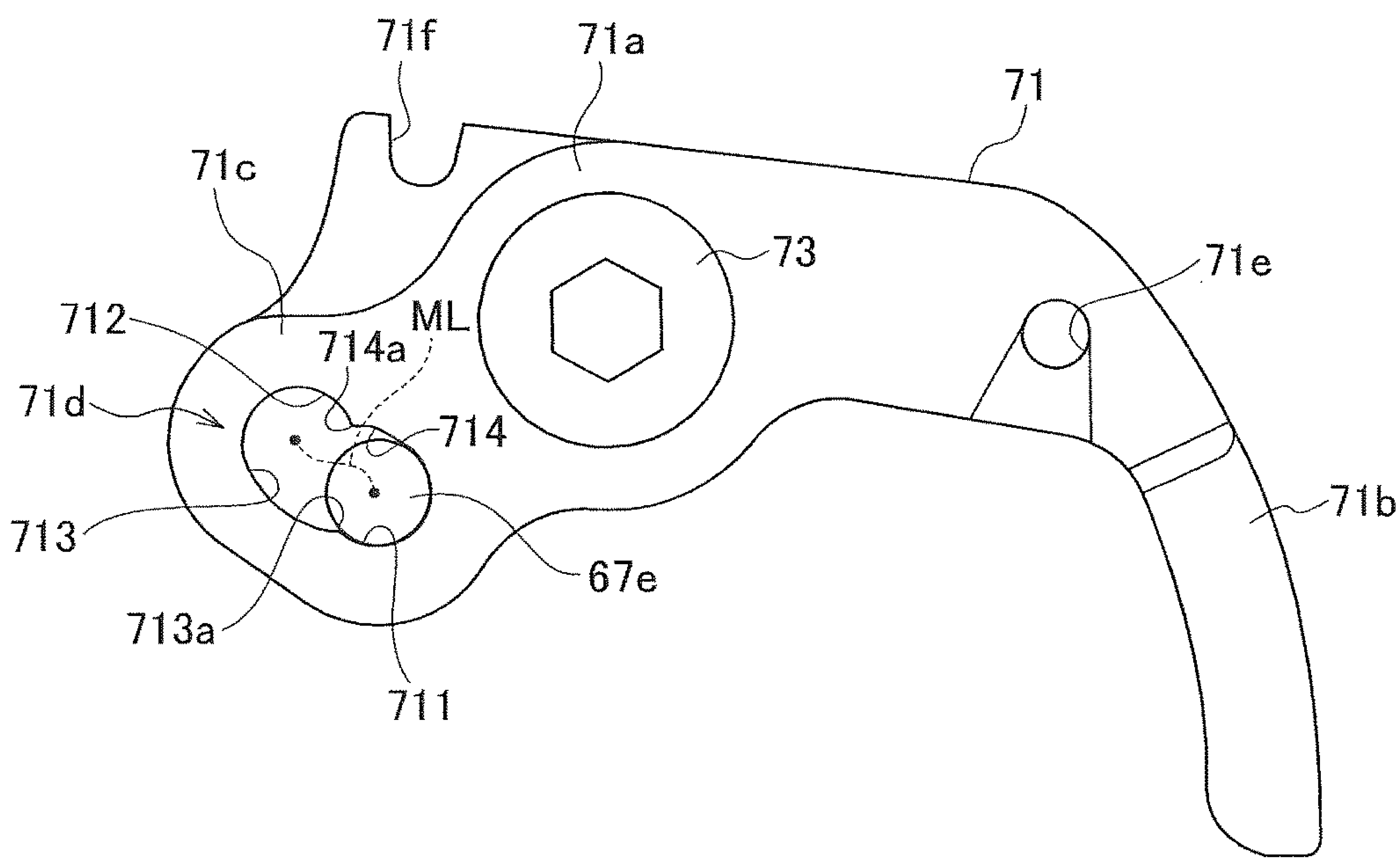
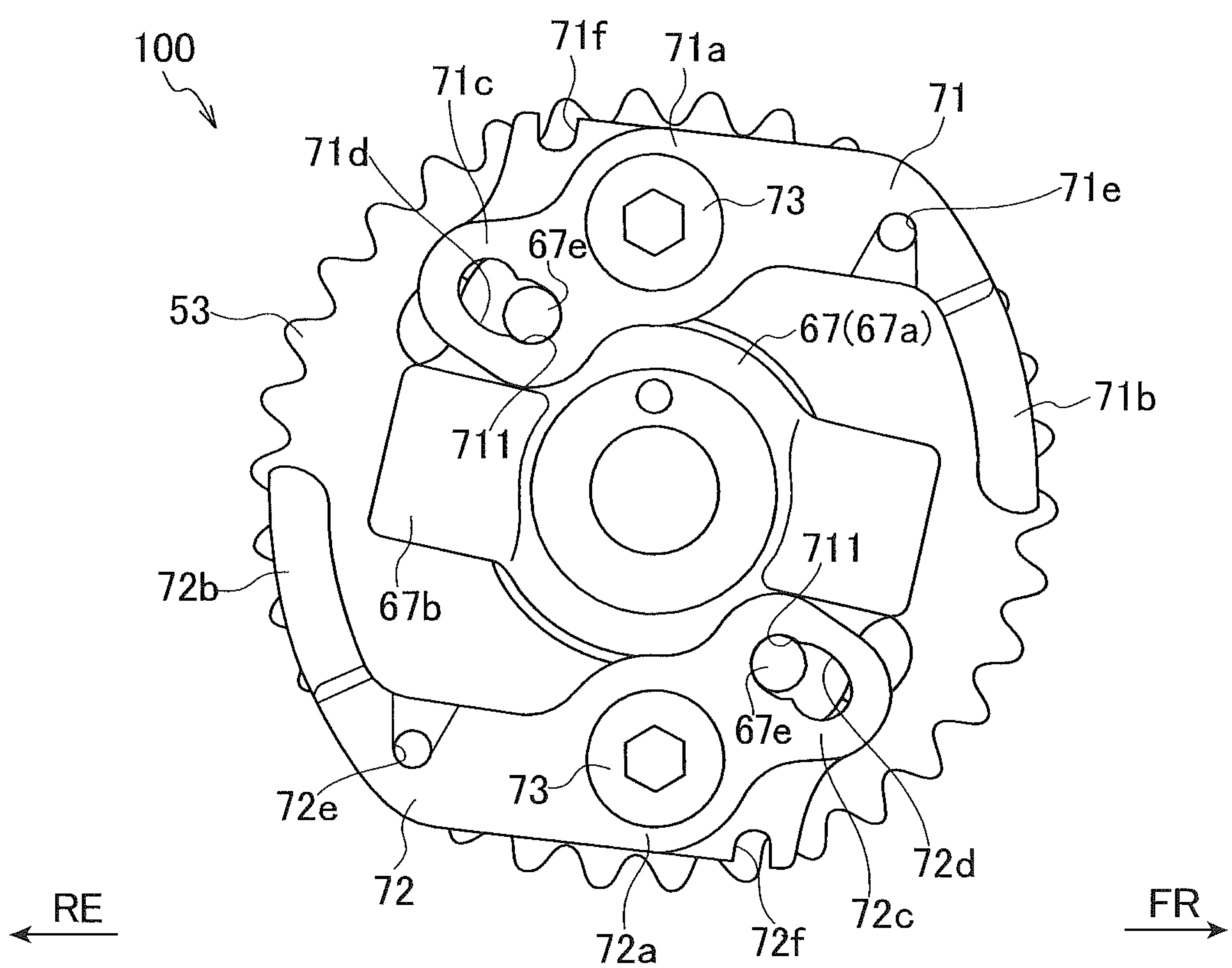


FIG. 9A



100
71f
71a
71c
71
71d
73
71e
67e
53
67(67a)
71b
711
711
72b
67b
67e
72e
73
72d
72
72c
RE
FR
72a
72f

FIG. 9B

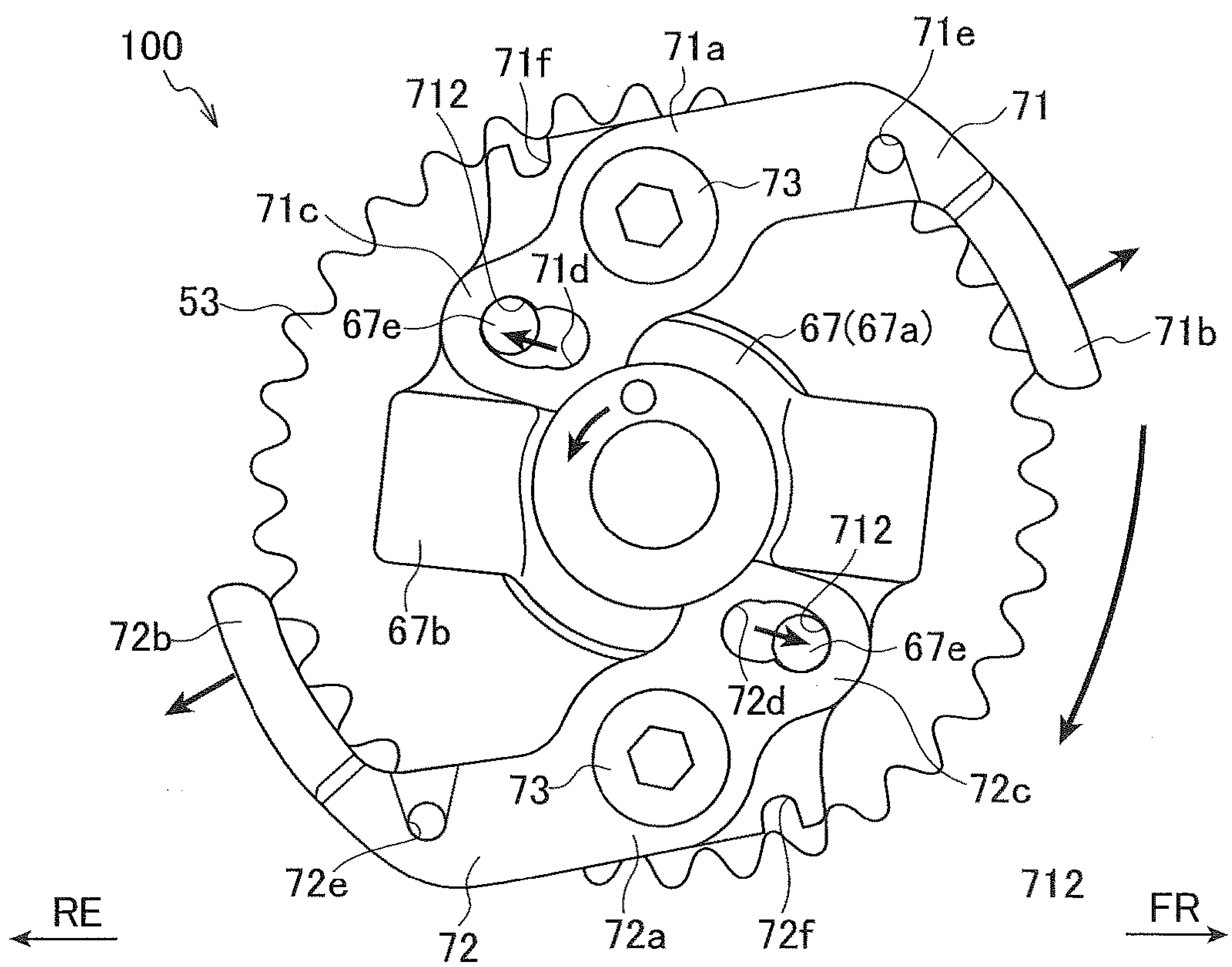
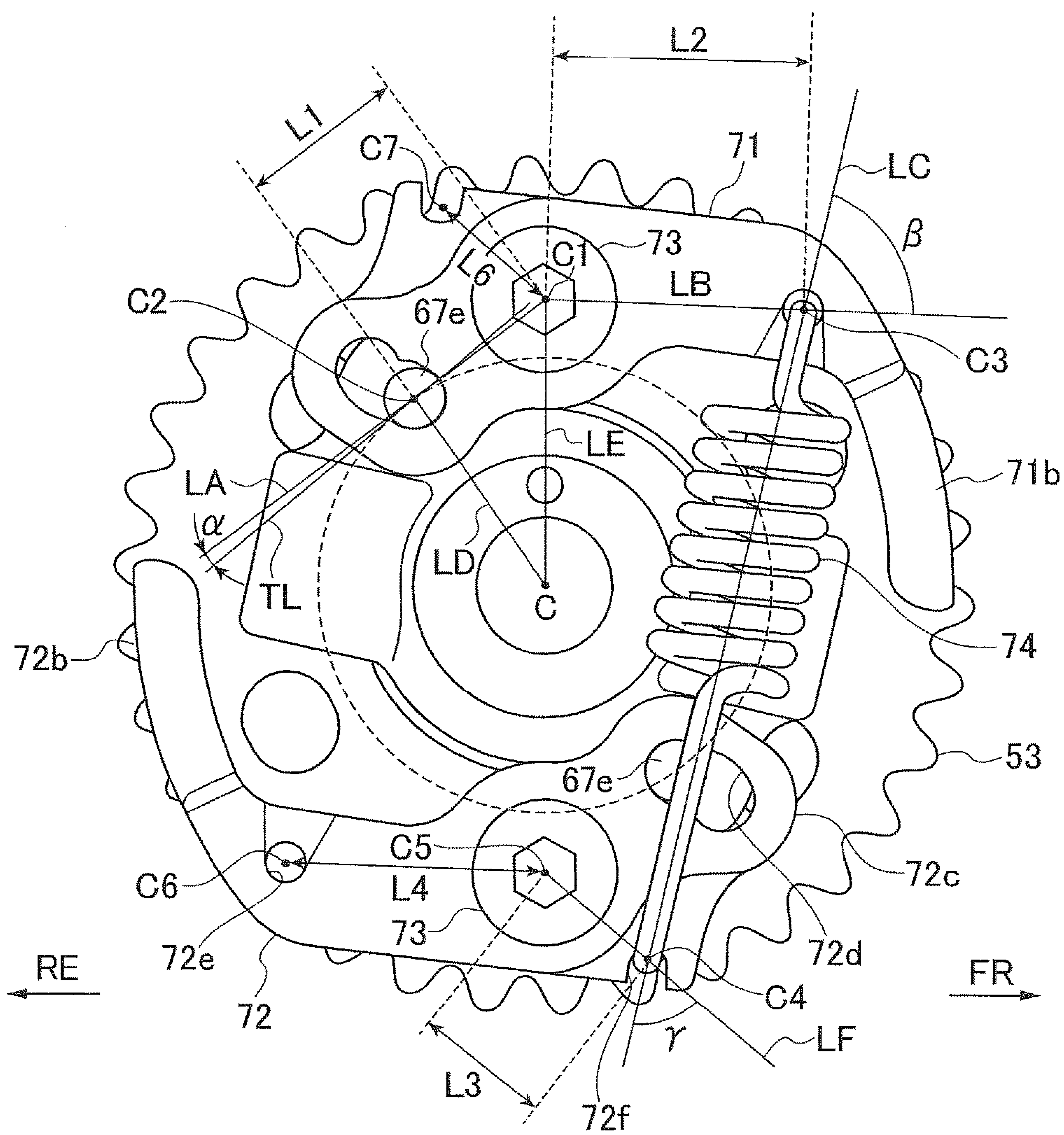

100
712
71f
71a
71e
71
73
71c
71d
53
67e
67(67a)
71b
712
67b
72b
67e
72d
73
72c
72e
712
RE
FR
72
72a
72f

FIG. 10



L1
L2
C7
71
LC
β
L6
C1
73
LB
C2
67e
C3
LE
71b
LA
α
LD
TL
C
74
72b
53
67e
C5
72c
C6
L4
73
72d
72e
C4
RE
FR
72
γ
LF
L3
72f

VARIABLE VALVE MECHANISM, ENGINE, AND AUTOMATIC TWO-WHEELED VEHICLE

INCORPORATION BY REFERENCE

This application is based upon and claims the benefit of priority from the corresponding Japanese Patent Application No. 2016-133288 filed on Jul. 5, 2016, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a variable valve mechanism, an engine, and an automatic two-wheeled vehicle, and particularly, to a variable valve mechanism which can be applied to a single overhead camshaft (SOHC) type valve train, an engine, and an automatic two-wheeled vehicle.

BACKGROUND ART

Hitherto, as an engine of an automatic two-wheeled vehicle, there is known an engine including a variable valve mechanism changing operation characteristics (including a valve opening/closing timing or a valve lift amount) of an intake valve and an exhaust valve in response to an engine rotation speed (for example, see JP 2011-1882 A). The variable valve mechanism described in JP 2011-1882 A includes a first driven member that is rotatable relatively to a cam shaft by a rotation transmitted from a crank shaft, a second driven member that is rotatable relatively to the first driven member and is relatively displaceable in the axial direction, and a centrifugal weight that is disposed between the first driven member and the second driven member. When the centrifugal weight moves by the action of a centrifugal force so that the second driven member is displaced relatively to the first driven member in the rotation direction, a phase of the cam shaft relatively to the crank shaft in the rotation direction is changed.

SUMMARY OF INVENTION

Technical Problem

However, in the variable valve mechanism described in JP 2011-1882 A, the second driven member is urged toward the first driven member by an urging member while the centrifugal weight is sandwiched between the first driven member and the second driven member. For this reason, since a resistance generated by the operation of the centrifugal weight is large, there is a need to perform a complex fine adjustment of the urging force in consideration of the influence of the resistance in order to smoothly change the phase of the cam shaft in the rotation direction.

The invention has been made in view of the above-described problems and an object of the invention is to provide a variable valve mechanism, an engine, and an automatic two-wheeled vehicle capable of more smoothly changing a phase of a cam shaft in a rotation direction.

Solution to Problem

An aspect of the present invention is summarized as a variable valve mechanism which changes an opening/closing timing of an intake valve or an exhaust valve in response to an engine rotation speed, the variable valve mechanism including: a cam sprocket which rotates in response to a rotation of a crank shaft; a cam shaft which is integrated with any one of intake side and exhaust side cams and is provided to be rotatable relatively to the cam sprocket; and a link member that engages with the cam sprocket and the cam shaft and transmits a rotation from the cam sprocket to the cam shaft, wherein the link member is supported by the cam sprocket to be swingable and swings in response to a change in rotation speed of the cam sprocket to rotate the cam shaft relatively to the cam sprocket.

According to this configuration, the link member swings in accordance with the rotation of the cam sprocket so that the cam shaft rotates relatively to the cam sprocket. For this reason, it is possible to change the phase of the cam shaft in the rotation direction by the swing operation of the link member. Accordingly, it is possible to suppress a resistance during an operation to be low compared to a conventional configuration in which the centrifugal weight is sandwiched between the pair of driven members. As a result, it is possible to more smoothly change the phase of the cam shaft in the rotation direction.

For example, in the above mentioned variable valve mechanism according to the present invention, the link member can include: a swing shaft which is fixed to the cam sprocket; a weight portion which is disposed to be separated from the swing shaft; and an engagement portion which engages with an engagement pin provided in the cam shaft and transmits a rotation of the cam sprocket to the cam shaft; the link member can be supported by the cam sprocket to be swingable; and the weight portion can move outward in the radial direction of the cam sprocket and the engagement portion moves to move the engagement pin in accordance with the rotation of the cam sprocket so that the cam shaft rotates relatively to the cam sprocket. According to this configuration, the weight portion moves outward in the radial direction of the cam sprocket and the engagement portion moves to move the engagement pin in accordance with the rotation of the cam sprocket so that the cam shaft rotates relatively.

Accordingly, it is possible to relatively rotate the cam shaft by swinging the link member using the centrifugal force generated in accordance with the rotation of the cam sprocket. For this reason, it is possible to stably change the phase of the cam shaft in the rotation direction with a simple and easy configuration without requiring a special control mechanism for relatively rotating the cam shaft. Further, since a friction force for the swing shaft is small and the weight portion can be moved even when a change in torque of the engine does not occur, it is possible to easily perform an inspection or an operation check of the cam shaft.

The above mentioned variable valve mechanism according to the present invention can further include: an urging member that is locked to the link member and urges the weight portion inward in the radial direction of the cam sprocket, wherein in a non-swing state of the link member, a distance L**1** between a center of the swing shaft and a center of the engagement pin can be smaller than a distance L**2** of an imaginary line connecting the center of the swing shaft to a locking position of the urging member on the link member. According to this configuration, since a distance between the swing shaft and the engagement pin is set to be small, it is possible to suppress a rotation moment for swinging the link member to be small when a driving reaction force given from the intake valve (the exhaust valve) to the cam is transmitted to the link member through the cam shaft and the engagement portion. Accordingly, it is possible to prevent a problem in which the link member easily swings.

In the above mentioned variable valve mechanism according to the present invention, in the non-swing state of the link member, an angle α formed by an imaginary line connecting the center of the swing shaft and the center of the engagement pin and a tangential line of a circle using a rotation axis of the cam shaft as a center and passing through the center of the engagement pin can be smaller than an angle β formed by an imaginary line connecting the center of the swing shaft and the locking position of the urging member and a center line of the urging member. According to this configuration, since the angle α is set to be smaller than the angle β, the rotation moment for swinging the link member when the driving reaction force given from the intake valve (the exhaust valve) to the cam is transmitted to the link member through the cam shaft and the engagement portion can be suppressed to be smaller than the rotation moment in which the urging member urges the link member. Accordingly, it is possible to prevent a problem in which the link member easily swings.

In the above mentioned variable valve mechanism according to the present invention, in the non-swing state of the link member, an imaginary line connecting the center of the swing shaft to the center of the engagement pin can intersect at a substantially right angle to an imaginary line connecting the center of the rotation axis of the cam shaft and the center of the engagement pin. According to this configuration, the swing shaft is disposed in the vicinity of the movement direction accompanied by the rotation of the cam shaft, that is, the tangential direction in the non-swing state. For this reason, even when the driving reaction force given from the intake valve (the exhaust valve) to the cam is transmitted to the link member through the cam shaft and the engagement portion, most elements of the driving reaction force can be set as an element for pulling the swing shaft. Accordingly, since the rotation moment for swinging the link member can be suppressed to maximum, it is possible to prevent a problem in which the link member easily swings.

For example, in the above mentioned variable valve mechanism according to the present invention, the engagement portion can be formed as a groove; and the groove can be provided with a first holding position which receives the engagement pin while the link member does not swing to a predetermined position or more and a second holding position which receives the engagement pin while the link member swings to a predetermined position or more and a first stopper portion which protrudes toward a facing inner wall surface of the groove in the vicinity of the first holding position is provided in an inner wall surface disposed at a farther side from the swing shaft in the inner wall surface of the groove. According to this configuration, since the first stopper portion which protrudes toward the facing inner wall surface of the groove in the vicinity of the first holding position is provided in the inner wall surface disposed at a farther side from the swing shaft in the inner wall surface of the groove, the engagement pin received in the first holding position cannot move easily. Accordingly, it is possible to suppress the vibration of the link member even when the driving reaction force given from the intake valve (the exhaust valve) to the cam is transmitted to the link member through the cam shaft and the engagement portion.

In the above mentioned variable valve mechanism according to the present invention, a second stopper portion which protrudes toward a facing inner wall surface of the groove in the vicinity of the second holding position can be provided in the inner wall surface disposed at a close side to the swing shaft in the inner wall surface of the groove. According to this configuration, since the second stopper portion which protrudes toward the facing inner wall surface of the groove in the vicinity of the second holding position is provided in the inner wall surface disposed at a close side to the swing shaft in the inner wall surface of the groove, the engagement pin received in the second holding position cannot move easily. Accordingly, it is possible to suppress the vibration of the link member even when the driving reaction force given from the intake valve (the exhaust valve to the cam is transmitted to the link member through the cam shaft and the engagement portion.

Especially, in the above mentioned variable valve mechanism according to the present invention, the groove can be provided with a substantially S-shaped moving line in which the center of the engagement pin in a front view bypasses the first stopper portion and the second stopper portion. According to this configuration, since the groove is provided with the substantially S-shaped moving line in which the center of the engagement pin bypasses the first stopper portion and the second stopper portion, it is possible to prevent a problem in which the engagement pin received in the first holding position or the second holding position moves easily. Accordingly, it is possible to swing the link member and to return the link member to the non-swing state at a desired timing.

In the above mentioned variable valve mechanism according to the present invention, the urging member can be disposed so that one end thereof is locked to a position near the weight portion in relation to the swing shaft and an angle β interposing the rotation axis of the cam sprocket among angles formed by an imaginary line passing through the locking position of the urging member and the center of the swing shaft and the center line of the urging member becomes an acute angle. According to this configuration, since the angle β which decreases in accordance with an increase in swing angle of the link member is set to an acute angle in advance, it is possible to increase the rotation radius of the weight portion in accordance with an increase in swing angle of the link member and to increase the centrifugal force applied to the weight portion in proportional to the rotation radius. Since the urging force increases as the swing angle of the link member increases in accordance with an increase in rotation speed of the cam sprocket, the link member can be immediately operated. Meanwhile, the link member can be returned to the non-swing state in accordance with a decrease in rotation speed of the cam sprocket. As a result, it is possible to improve the responsiveness of the operation of the link member in response to the rotation speed of the cam sprocket.

For example, in the above mentioned variable valve mechanism according to the present invention, the link member can include a first link member disposed at one side with the rotation axis of the cam sprocket interposed therebetween and a second link member disposed at the other side; and the urging member can include a first urging member disposed at one side with the rotation axis of the cam sprocket interposed therebetween and a second urging member disposed at the other side. According to this configuration, since the first link member and the second link member are disposed at the opposite side with the rotation axis of the cam sprocket interposed therebetween and the first urging member and the second urging member are disposed at the opposite side with the rotation axis of the cam sprocket interposed therebetween, it is possible to dispose the link member and the urging member with a good balance. For this reason, it is possible to keep the smooth rotation of the cam shaft without requiring a weight portion for ensuring a balance.

Especially, in the above mentioned variable valve mechanism according to the present invention, the first link member and the second link member can be disposed to be point-symmetrical to each other with respect to the center of the rotation axis of the cam sprocket and the first urging member and the second urging member are disposed to be point-symmetrical to each other with respect to the center of the rotation axis of the cam sprocket. According to this configuration, since the first link member and the second link member are disposed to be point-symmetrical to each other with respect to the center of the rotation axis of the cam sprocket, it is possible to transmit a rotation force from the cam sprocket through a plurality of link members to be symmetrical each other with respect to the cam shaft. Accordingly, it is possible to smoothly rotate the cam shaft. Further, since the first link member and the second link member are disposed to be point-symmetrical to each other with respect to the center of the rotation axis of the cam sprocket, it is possible to keep the smooth rotation of the cam shaft without requiring a weight portion for ensuring a balance.

In the above mentioned variable valve mechanism according to the present invention, in the first link member and the second link member, the weight portion can be disposed at one side and the engagement portion is disposed at the other side with respect to an imaginary line connecting the center of the swing shaft and the center of the rotation axis of the cam sprocket; one end of the first urging member can be locked to a position near the weight portion in relation to the swing shaft of the first link member and the other end thereof is locked to a position near the engagement portion in relation to the swing shaft of the second link member; and one end of the second urging member can be locked to a position near the weight portion in relation to the swing shaft of the second link member and the other end thereof is locked to a position near the engagement portion in relation to the swing shaft of the first link member. According to this configuration, both the first urging member and the second urging member are locked in the first link member and the second link member. For this reason, when one ends (ends on the side of the weight portion) of the first urging member and the second urging member are pulled outward in the radial direction of the cam sprocket, the other ends (ends on the side of the engagement portion) of the second urging member and the first urging member move inward in the radial direction of the cam sprocket. Accordingly, since the expansion/contraction amounts of the first urging member and the second urging member can be decreased, a burden on the urging member can be reduced. Further, since both ends of the first urging member and the second urging member are locked to the first link member and the second link member, no interference occurs since the urging member is also operated when the link member swings. For this reason, since the first link member and the second link member can be disposed at a close position, the variable valve mechanism can have a simple and compact structure.

In the above mentioned variable valve mechanism according to the present invention, a distance between a locking position of the first urging member at the side of the weight portion in the first link member and the center of the swing shaft of the first link member can be larger than a distance between a locking position of the first urging member at the side of the engagement portion in the second link member and the center of the swing shaft of the second link member; and a distance between a locking position of the second urging member at the side of the weight portion in the second link member and the center of the swing shaft of the second link member can be larger than a distance between a locking position of the second urging member at the side of the engagement portion in the first link member and the center of the swing shaft of the first link member. According to this configuration, even in a structure which pulls both the weight portion and the engagement portion of the plurality of link members, the rotation moment at the weight portion is larger than the rotation moment at the engagement portion and thus both link members can be urged in a non-swing direction. Accordingly, it is possible to stably change the phase of the cam shaft in the rotation direction even when the locking position of the urging member is provided at both the weight portion and the engagement portion in the narrow space.

Further, it is preferable that the engine according to the invention include the variable valve mechanism. According to this configuration, an effect obtained by the variable valve mechanism can be also obtained by the engine.

Further, it is preferable that an automatic two-wheeled vehicle according to the invention include an engine. According to this configuration, an effect obtained by the engine can be also obtained by the automatic two-wheeled vehicle.

According to the invention, it is possible to more smoothly change the phase of the rotation direction of the cam shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view illustrating a schematic configuration of an automatic two-wheeled vehicle including an engine that adopts a variable valve mechanism according to an embodiment;

FIG. **2** is a perspective view of a valve train according to the embodiment;

FIG. **3** is a perspective view illustrating a part of the variable valve mechanism that is assembled to the valve train according to the embodiment;

FIG. **4** is an exploded perspective view of the variable valve mechanism illustrated in FIG. **3**;

FIG. **5** is an exploded perspective view of a cam shaft assembly according to the embodiment;

FIG. **6** is a cross-sectional view of the variable valve mechanism illustrated in

FIG. **3**;

FIG. **7** is a side view of the variable valve mechanism illustrated in FIG. **3**;

FIG. **8** is an enlarged view of a link member that belongs to the variable valve mechanism according to the embodiment;

FIGS. **9**A and **9**B are diagrams illustrating a positional relation of components of a link member of the variable valve mechanism according to the embodiment; and

FIG. **10** is a diagram illustrating an operation of the variable valve mechanism according to the embodiment.

DESCRIPTION OF EMBODIMENTS

Hereinafter, an embodiment of the invention will be described in detail with reference to the accompanying drawings. Further, in the following description, an example in which a variable valve mechanism according to the invention is applied to an engine of an automatic two-wheeled vehicle will be described, but the application target can be changed without limitation. For example, the variable valve mechanism according to the invention may be also applied to engines of other automatic two-wheeled vehicles, buggy type automatic three-wheeled vehicles, or automatic four-wheeled vehicles. Regarding the direction, the front side of the vehicle will be denoted by an arrow FR, the rear side of the vehicle will be denoted by an arrow RE, the left side of the vehicle will be denoted by L, and the right side of the vehicle will be denoted by an arrow R. Further, in the drawings below, a part of the configuration will be omitted for convenience of the description.

Referring to FIG. **1**, a schematic configuration of an automatic two-wheeled vehicle that employs an engine according to the embodiment will be described. FIG. **1** is a side view illustrating a schematic configuration of an automatic two-wheeled vehicle including an engine that employs the variable valve mechanism according to the embodiment.

As illustrated in FIG. **1**, an automatic two-wheeled vehicle **1** has a configuration in which an engine **2** is suspended on a vehicle body frame **10** formed of aluminum alloy or a steel product equipped with a power unit, an electricity system, and the like. The engine **2** is, for example, a single cylinder four-cycle engine. The engine **2** has a configuration in which a cylinder assembly **20** (hereinafter, simply referred to as a cylinder **20**) obtained by the combination of a cylinder block or a cylinder head is attached to an upper portion of a crank casing **21**.

Components such as a piston (not illustrated) or a valve train **5** (see FIG. **2**) are received inside the cylinder **20**. Although it will be described later in detail, the valve train **5** according to the embodiment is configured as a single overhead camshaft (SOHC) type valve train. Further, various shafts that transmit a rotation of a crank shaft (not illustrated) are received inside the crank casing **21** in addition to the crank shaft.

An exhaust pipe **11** is connected to a front exhaust port of the engine **2**. The exhaust pipe **11** extends downward from the exhaust port, is bent under the crank casing **21**, and extends toward the rear side of the vehicle body. A muffler **12** is attached to a rear end of the exhaust pipe **11**. An exhaust gas which is produced after combustion is discharged to the outside through the exhaust pipe **11** and the muffler **12**.

A fuel tank **13** is disposed at an upper portion of the vehicle body frame **10**. A driver seat **14** and a passenger seat **15** are disposed at the rear side of the fuel tank **13** along with a rear cowl **16**. A pair of left and right front forks **30** are supported by a front head portion of the vehicle body frame **10** to be steerable along with a handlebar **31**. A head lamp **32** is provided at the front side of the handlebar **31**. A front wheel **33** is supported by a lower portion of the front fork **30** to be steerable and an upper portion of the front wheel **33** is covered by a front fender **34**.

A swing arm (not illustrated) is connected to a rear portion of the vehicle body frame **10** to be swingable up and down. A rear wheel **40** is supported by the rear portion of the swing arm to be rotatable. A driven sprocket (not illustrated) is provided at the left side of the rear wheel **40** and power of the engine **2** is transmitted to the rear wheel **40** by a drive chain (not illustrated). An upper portion of the rear wheel **40** is covered by a rear fender **41** provided at a rear portion of the rear cowl **16**.

Next, the valve train according to the embodiment will be described with reference to FIGS. **2** and **3**. FIG. **2** is a diagram illustrating a state where a cylinder head cover is separated from the engine and is a perspective view of the valve train according to the embodiment. FIG. **3** is a perspective view illustrating a part of a variable valve mechanism that is assembled to the valve train according to the embodiment.

As illustrated in FIG. **2**, the valve train **5** which controls the opening/closing of an intake valve **50** and an exhaust valve **51** is provided at an upper portion of the cylinder **20**. As described above, the valve train **5** is an SOHC type valve train and has a configuration in which a cam shaft assembly **6** (hereinafter, simply referred to as a cam shaft **6**) is disposed above the intake valve **50** and the exhaust valve **51**.

Two intake valves **50** are disposed at the cam shaft **6** on the rear side of the vehicle to be arranged in the left and right direction (the vehicle width direction). Further, two exhaust valves **51** are disposed at the cam shaft **6** on the front side of the vehicle to be arranged in the left and right direction. Each of the intake valves **50** and the exhaust valves **51** is provided with a valve spring **52**. The intake valves **50** and the exhaust valves **51** are constantly urged upward (in a closing direction) by the valve springs **52**.

The cam shaft **6** extends in the left and right direction (see FIG. **3**). An intake cam **62** and an exhaust cam **63** are provided at the cam shaft **6** to be arranged in the left and right direction (the intake cam **62** is not illustrated in FIG. **2**, but is illustrated in FIG. **3**). Specifically, as illustrated in FIGS. **2** and **3**, the left side in the axial direction is the intake cam **62** and the right side in the axial direction is the exhaust cam **63**. Further, a right end of the cam shaft **6** is provided with a cam sprocket **53**. A cam chain (not illustrated) which transmits the rotation of the crank shaft is wound around the cam sprocket **53**.

For example, the cam shaft **6** is obtained by coaxially assembling an intake cam shaft **60** constituting a first cam shaft and an exhaust cam shaft **61** constituting a second cam shaft (see FIGS. **4** and **5**). Although a detailed description will be made below, the cam shaft **6** and the peripheral components thereof constitute a variable valve mechanism **100** which changes the opening/closing timings of the intake valve **50** and the exhaust valve **51**.

As illustrated in FIG. **2**, an intake rocker arm **54** which opens and closes the intake valve **50** and an exhaust rocker arm **55** which opens and closes the exhaust valve **51** are provided above the cam shaft **6** (the intake cam **62** and the exhaust cam **63**). The intake rocker arm **54** is supported to be swingable by an intake rocker shaft (not illustrated) extending in the left and right direction. Specifically, the intake rocker arm **54** includes a support portion **54***a* which serves as a swing support point, a contact portion **54***b* which contacts the intake cam **62**, and a pressing portion **54***c* which presses the intake valve **50**.

The support portion **54***a* has a cylindrical shape through which the intake rocker shaft is insertable. The contact portion **54***b* extends forward and downward from the support portion **54***a* and a roller **54***d* is attached to a front end thereof. An outer surface of the roller **54***d* is in contact with an outer surface of the intake cam **62**. The pressing portion **54***c* is bifurcated backward and downward from the support portion **54***a* and front ends thereof are in contact with an upper end of the intake valve **50**.

The exhaust rocker arm **55** is also supported to be swingable by an exhaust rocker shaft (not illustrated) extending in the left and right direction. Specifically, the exhaust rocker arm **55** includes a support portion **55***a* which serves as a swing support point, a contact portion **55***b* which contacts the exhaust cam **63**, and a pressing portion **55***c* which presses the exhaust valve **51**.

The support portion **55***a* has a cylindrical shape through which the exhaust rocker shaft is insertable. The contact portion **55***b* extends backward and downward from the support portion **55***a* and a roller **55***d* is attached to a front end thereof. An outer surface of the roller **55***d* is in contact with an outer surface of the exhaust cam **63**. The pressing portion **55***c* is bifurcated forward and downward from the support portion **55***a* and front ends thereof are in contact with an upper end of the exhaust valve **51**.

In the valve train **5** with such a configuration, when the cam shaft **6** rotates along with the rotation of the crank shaft, the contact portion **54***b* (the contact portion **54***b*) slides along a cam surface (the outer surface) of the intake cam **62** (the exhaust cam **63**). Especially, the contact portion **54***b* (the contact portion **55***b*) is pressed upward by a protruding portion of the intake cam **62** (the exhaust cam **63**). For this reason, the intake rocker arm **54** (the exhaust rocker arm **55**) rotates about the support portion **54***a* (the support portion **55***a*) as a support point and the pressing portion **54***c* (the pressing portion **55***c*) moves downward.

At this time, the pressing portion **54***c* (the pressing portion **55***c*) presses the intake valve **50** (the exhaust valve **51**) downward (in an opening direction) against an urging force of the valve spring **52**. As a result, the intake valve **50** (the exhaust valve **51**) is opened. When the contact portion **54***b* (the contact portion **55***b*) gets over the protruding portion of the intake cam **62** (the exhaust cam **63**), the intake valve **50** (the exhaust valve **51**) is urged upward by the urging force of the valve spring **52**. As a result, the intake valve **50** (the exhaust valve **51**) is closed. In this way, the opening and closing of the intake valve **50** and the exhaust valve **51** is controlled.

Next, the variable valve mechanism **100** that is assembled to the valve train **5** according to the embodiment will be described with reference to FIGS. **3** and **4**. FIG. **4** is an exploded perspective view of the variable valve mechanism **100** illustrated in FIG. **3**. Additionally, FIGS. **3** and **4** illustrate a state (a non-swing state) where a pair of link members **7** (a first link member **71** and a second link member **72**) constituting the variable valve mechanism **100** do not swing.

As described above, the valve train **5** according to the embodiment (see FIG. **2**) includes the variable valve mechanism **100** which changes the opening and closing timing of the intake valve **50** or the exhaust valve **51** (see FIG. **2**) in response to an engine rotation speed. As illustrated in FIG. **3**, the variable valve mechanism **100** is a so-called governor type variable valve timing mechanism which advances the valve timing of the intake valve **50** by using a centrifugal force generated by the rotation of the cam shaft **6** (the cam sprocket **53**).

As illustrated in FIGS. **3** and **4**, the variable valve mechanism **100** includes the cam shaft **6**, the cam sprocket **53**, and the pair of link members **7** (the first link member **71** and the second link member **72**). The cam sprocket **53** is provided at a right end of the cam shaft **6** and the pair of link members **7** are attached to a right surface of the cam sprocket **53**. Hereinafter, components of the variable valve mechanism **100** will be described.

First, a configuration of the cam shaft **6** including the variable valve mechanism **100** according to the embodiment will be described. FIG. **5** is an exploded perspective view of the cam shaft **6** according to the embodiment. FIG. **6** is a cross-sectional view of the variable valve mechanism **100** illustrated in FIG. **3**. In FIG. **5**, a link flange **67** constituting a part of the cam shaft **6** is omitted for convenience of the description.

As illustrated in FIGS. **5** and **6**, the cam shaft **6** has a configuration in which a sprocket flange **66** is attached to a right end of the exhaust cam shaft **61** through a bearing **65**, the cylindrical exhaust cam shaft **61** is attached to the intake cam shaft **60**, and an link flange **67** is attached to a right end of the intake cam shaft **60** (the link flange **67** is not illustrated in FIG. **5**, but is illustrated in FIG. **4**).

The intake cam shaft **60** is formed in a hollow shape and extends in the left and right direction. The intake cam **62** is integrally formed at the left end of the intake cam shaft **60**. A screw hole **60***a* for a bolt **68** (see FIGS. **4** and **6**) to be described later is provided at the right end of the intake cam shaft **60**. Further, an engagement groove **60***b* which engages with an engagement pin **67***d* of the link flange **67** is formed at the outer peripheral side of the right end of the intake cam shaft **60**.

Further, a portion which is located on the right side of the intake cam **62** in the intake cam shaft **60** and is received inside the exhaust cam shaft **61** is formed so that a base end and a right end are larger (thicker) than an intermediate portion **60***e* in the radial direction. The thick portion of the intake cam shaft **60** serves as a support portion **60***c* which supports the exhaust cam shaft **61**. Specifically, an outer diameter of the support portion **60***c* is substantially equal to an inner diameter of the exhaust cam shaft **61**. Further, an outer surface of the support portion **60***c* is provided with an annular groove **60***d*. The annular groove **60***d* and the intermediate portion **60***e* serve as an oil supply path which supplies oil to a sliding surface between the intake cam shaft **60** and the exhaust cam shaft **61**.

The exhaust cam shaft **61** is formed such that the exhaust cam **63** is integrally formed at a left end, that is, an end opposite to the sprocket flange **66** and has a cylindrical shape through which the intake cam shaft **60** is insertable. Specifically, an inner diameter of the exhaust cam shaft **61** is set to be slightly larger than an outer diameter of the intake cam shaft **60**. A length of the exhaust cam shaft **61** is substantially the same as a length of the intake cam shaft **60** on the right side of the intake cam **62**. Further, the exhaust cam shaft **61** and the intake cam shaft **60** are formed to be rotatable relatively to each other.

The sprocket flange **66** which is provided at the right end of the exhaust cam shaft **61** is provided with two screw holes **66***a* corresponding to the penetration hole **53**b of the cam sprocket **53**. The sprocket flange **66** is attached to the exhaust cam shaft **61** to be rotatable together. Further, the cam sprocket **53** is fixed to the sprocket flange **66** by a bolt **73** to be described later.

The link flange **67** includes, as illustrated in FIG. **4**, a circular portion **67***a* which engages with the intake cam shaft **60** and a flange portion **67***b* which is widened outward in the radial direction from the outer periphery of the circular portion **67***a*. A circular hole **67***c* is formed at the center of the circular portion **67***a*. When the bolt **68** is inserted through the circular hole **67***c* and the bolt **68** is threaded into the intake cam shaft **60**, the link flange **67** is fixed to the intake cam shaft **60**. Additionally, the link flange **67** is fixed to the intake cam shaft **60** with the cam sprocket **53** interposed therebetween.

The engagement pin **67***d* is attached to the circular portion **67***a* at a position separated from the center in the radial direction. The engagement pin **67***d* protrudes toward the intake cam shaft **60**. When the engagement pin **67***d* engages with the engagement groove **60***b* of the intake cam shaft **60**, the link flange **67** and the intake cam shaft **60** rotate together. The flange portion **67***b* is provided with two engagement pins **67***e* which protrude outward in the axial direction (rightward). The engagement pins **67***e* engage with engagement grooves **71***d* and **72***d* of the first link member **71** and the second link member **72** to be described later.

As illustrated in FIG. **4**, the cam sprocket **53** is disposed between the sprocket flange **66** and the link flange **67** of the cam shaft **6**. A circular hole **53***a* is formed at the center of the cam sprocket **53**. Further, a side surface of the cam sprocket **53** is provided with two penetration holes **53***b* which serve as swing support points of the pair of link members **7**. Two penetration holes **53***b* are disposed at positions facing each other with the circular hole **53***a* interposed therebetween.

Next, a configuration of the pair of link members **7** of the variable valve mechanism **100** according to the embodiment will be described with reference to FIG. **7**. FIG. **7** is a side view of the variable valve mechanism **100** illustrated in FIG. **3**. FIG. **7** illustrates the variable valve mechanism **100** illustrated in FIG. **3** from the right side. Further, for convenience of the description, the bolt **68** which fixes the link flange **67** to the intake cam shaft **60** is not illustrated in FIG. **7**. FIG. **7** illustrates a state (a non-swing state) where the pair of link members **7** do not swing. The same applies to FIGS. **8** and **10** below.

As illustrated in FIG. **7**, the pair of link members **7** include the first link member **71** and the second link member **72** which have the same configuration. The first link member **71** is disposed at the side opposite to the second link member **72** with the rotation axis of the cam sprocket **53** (the cam shaft **6**) interposed therebetween. More specifically, the first link member **71** and the second link member **72** are disposed to be point-symmetrical to each other with respect to the center C of the rotation axis of the cam sprocket **53** and the cam shaft **6**.

The first link member **71** is formed in a substantially crescent shape along the circumferential direction of the cam sprocket **53**. The first link member **71** includes a support portion **71***a* which is supported by the cam sprocket **53** to be swingable (rotatable), a weight portion **71***b* which is formed to be separated from the support portion **71***a*, and an engagement portion **71***c* which engages with a part (the engagement pin **67***e*) of the link flange **67** (see FIG. **4**). A locking hole **71***e* which locks one end of a first spring **74** to be described later is formed between the support portion **71***a* and the weight portion **71***b*. The locking hole **71***e* is disposed in the vicinity of a base end of the weight portion **71***b*. Further, a locking portion **71***f* which locks the other end of a second spring **75** to be described later is formed above the engagement portion **71***c*.

The support portion **71***a* is formed in a cylindrical shape through which the bolt **73** is insertable. The bolt **73** which is inserted through the support portion **71***a* and is fixed to the sprocket flange **66** through the cam sprocket **53** serves as a swing shaft of the first link member **71**. The first link member **71** extends from the support portion **71**a toward the front side in the rotation direction and a front end thereof is slightly bent inward in the radial direction. The bent front end portion is formed as the weight portion **71***b*. Further, the engagement portion **71***c* extends from the support portion **71***a* toward the rear side in the rotation direction and a rear end thereof is slightly located at the inside in the radial direction in relation to the support portion **71***a*. The rear end portion of the engagement portion **71***c* is provided with the engagement groove **71***d* which engages with the engagement pin **67***e*.

Similarly to the first link member **71**, the second link member **72** is formed in a substantially crescent shape along the circumferential direction of the cam sprocket **53**. The second link member **72** includes a support portion **72***a* which is supported by the cam sprocket **53** to be rotatable, a weight portion **72***b* which is formed to be separated from the support portion **72***a*, and an engagement portion **72***c* which engages with the link flange **67** (the engagement pin **67***e*). A locking hole **72***e* which locks one end of the second spring **75** to be described later is formed between the support portion **72***a* and the weight portion **72***b*. The locking hole **72***e* is provided in the vicinity of a base end of the weight portion **72***b*. Further, a locking portion **72***f* which locks the other end of the first spring **74** to be described later is formed below the engagement portion **72***c*.

The support portion **72***a* has a cylindrical shape through which the bolt **73** is insertable. The bolt **73** which is inserted through the support portion **72***a* and is fixed to the sprocket flange **66** through the cam sprocket **53** serves as a swing shaft of the second link member **72**. The second link member **72** extends backward in the rotation direction from the support portion **72***a* and a front end is slightly bent inward in the radial direction. The bent front end portion is formed as the weight portion **72***b*. Further, the engagement portion **72***c* slightly extends toward the front side in the rotation direction from the support portion **72***a* and a front end is slightly located at the inside of the radial direction in relation to the support portion **72***a*. The rear end portion of the engagement portion **72***c* is provided with the engagement groove **72***d* which engages with the engagement pin **67***e*.

The first link member **71** is attached to the cam sprocket **53** to be swingable when the bolt **73** is inserted through the penetration hole **53***b* of the cam sprocket **53** and the support portion **71***a* while the engagement pin **67***e* of the link flange **67** engages with the engagement groove **71***d* and the bolt **73** is threaded into the sprocket flange **66**. Similarly, the second link member **72** is attached to the cam sprocket **53** to be swingable when the bolt **73** is inserted through the penetration hole **53***b* of the cam sprocket **53** and the support portion **72***a* while the engagement pin **67***e* of the link flange **67** engages with the engagement groove **72***d* and the bolt **73** is threaded into the sprocket flange **66**.

Here, configurations of the engagement grooves **71***d* and **72***d* formed in the first link member **71** and the second link member **72** will be described with reference to FIG. **8**. FIG. **8** is an enlarged view of the link member **7** (the first link member **71**) of the variable valve mechanism **100** according to the embodiment. The engagement grooves **71***d* and **72***d* which are formed in the first link member **71** and the second link member **72** have the same configuration except for the direction. Here, a description will be made by using the engagement groove **71***d* of the first link member **71** and a description of the engagement groove **72***d* formed in the second link member **72** will be omitted.

As illustrated in FIG. **8**, the engagement groove **71***d* has an elongated hole shape which extends in the radial direction of the cam sprocket **53** while the first link member **71** does not swing. The engagement groove **71***d* includes a first holding position **711** which holds the engagement pin **67***e* in a state where the first link member **71** does not swing to a predetermined position or more (in other words, a state where the first link member **71** is closed) and a second holding position **712** which holds the engagement pin **67***e* in a state where the first link member **71** swings to a predetermined position or more (in other words, a state where the first link member **71** is opened). The first holding position **711** and the second holding position **712** are substantially circular. The engagement groove **71***d* includes the first holding position **711** and the second holding position **712** formed at both ends thereof and these holding positions are connected to each other.

A first stopper portion **713***a* which protrudes toward the facing inner wall surface **714** of the engagement groove **71***d* in the vicinity of the first holding position **711** is provided at the inner wall surface **713** disposed at a farther side from the bolt **73** in the inner wall surface of the engagement groove **71***d*. The first stopper portion **713***a* is used so that the engagement pin **67***e* received in the first holding position **711** does not easily move toward the second holding position **712**. Meanwhile, a second stopper portion **714***a* which protrudes toward the facing inner wall surface **713** of the engagement groove **71***d* in the vicinity of the second holding position **712** is provided at the inner wall surface **714** disposed at a close side to the bolt **73** in the inner wall surface of the engagement groove **71***d*. The second stopper portion **714***a* is used so that the engagement pin **67***e* received in the second holding position **712** does not easily move toward the first holding position **711**.

The engagement groove **71***d* is provided with a substantially S-shaped moving line ML in which the center of the engagement pin **67***e* bypasses the first stopper portion **713***a* and bypasses the second stopper portion **714***a*. That is, when the engagement pin **67***e* inside the engagement groove **71***d* moves from the first holding position **711** to the second holding position **712**, the engagement pin reaches the second holding position **712** along a path in which the center moves away from the first stopper portion **713***a* and moves away from the second stopper portion **714***a*.

Further, the first link member **71** and the second link member **72** are provided with a pair of springs (the first spring **74** and the second spring **75**) which respectively urge the weight portions **71***b* and **72***b* inward in the radial direction of the cam sprocket **53**. For example, these springs are formed as compression coil springs. The first spring **74** is disposed at the side opposite to the second spring **75** with the rotation axis of the cam sprocket **53** (the cam shaft **6**) interposed therebetween. More specifically, the first spring **74** and the second spring **75** are disposed to be point-symmetrical to each other with respect to the center C of the rotation axis of the cam sprocket **53** and the cam shaft **6**.

One end (an upper end) of the first spring **74** is locked to the locking hole **71***e* at the side of the weight portion **71***b* of the first link member **71**. Meanwhile, the other end (a lower end) of the first spring **74** is locked to the locking portion **72***f* at the side of the engagement portion **72***c* of the second link member **72**. Further, one end (a lower end) of the second spring **75** is locked to the locking hole **72***e* at the side of the weight portion **72***b* of the second link member **72**. Meanwhile, the other end (an upper end) of the second spring **75** is locked to the locking portion **71***f* at the side of the engagement portion **71***c* of the first link member **71**. Both ends of the first spring **74** and the second spring **75** are locked by the first link member **71** and the second link member **72** so that an urging force of pulling both link members inward in the radial direction of the cam sprocket **53** is exerted.

Next, an operation of the variable valve mechanism **100** with such a configuration will be described with reference to FIGS. **9**A and **9**B. FIGS. **9**A and **9**B are diagrams illustrating an operation of the variable valve mechanism **100** according to the embodiment. FIG. **9**A illustrates a state (a non-swing state: a closed state) where the pair of link members **7** do not swing and FIG. **9**B illustrates a state (a swing state: an opened state) where the pair of link members **7** swing to maximum. Further, for convenience of the description, the bolt **68**, the first spring **74**, and the second spring **75** are not illustrated in FIGS. **9**A and **9**B.

In the variable valve mechanism **100**, as illustrated in FIGS. **9**A and **9**B, the first link member **71** and the second link member **72** are urged inward in the radial direction of the cam sprocket **53** by the first spring **74** and the second spring **75**. For example, when an engine rotation speed is a predetermined rotation speed or less, centrifugal forces generated by the weight portions **71***b* and **72***b* are smaller than the urging forces of the first spring **74** and the second spring **75** as illustrated in FIG. **9**A. For this reason, the first link member **71** and the second link member **72** do not swing about the support portions **71***a* and **72***a* as swing support points.

Further, the weight portions **71***b* and **72***b* are located at positions not protruding outward in the radial direction from the outer edge of the cam sprocket **53**. At this time, the engagement pin **67***e* of the link flange **67** is received in the first holding position **711** at the inside of the engagement grooves **71***d* and **72***d* in the radial direction. In this case, the link flange **67** and the cam sprocket **53** rotate together without relative rotation. Accordingly, the intake cam shaft **60** and the exhaust cam shaft **61** (which are illustrated in FIG. **5**) which engage with the link flange **67** also rotate together with the cam sprocket **53**. As a result, in the valve train **5** (see FIG. **2**), the opening and closing of the intake valve **50** and the exhaust valve **51** is controlled at a normal valve timing.

Meanwhile, when an engine rotation speed exceeds a predetermined rotation speed, the centrifugal forces generated by the weight portions **71***b* and **72***b* become larger than the urging forces of the first spring **74** and the second spring **75**. For this reason, as illustrated in FIG. **9**B, the first link member **71** and the second link member **72** swing about the bolt **73** inserted through the support portions **71***a* and **72***a* and the weight portions **71***b* and **72***b* move outward in the radial direction of the cam sprocket **53**. Accordingly, the weight portions **71***b* and **72***b* are located at positions protruding outward in the radial direction from the outer edge of the cam sprocket **53**.

Further, when the first link member **71** and the second link member **72** swing, the engagement portions **71***c* and **72**C move inward in the radial direction. Accordingly, the link flange **67** rotates in the opposite direction relatively to the cam sprocket **53** while the engagement pin **67***e* is received in the second holding position **712** at the outside of the radial direction of the engagement grooves **71***d* and **72***d*. Accordingly, the intake side cam shaft **60** which engages with the link flange **67** rotates relatively to the cam sprocket **53**. As a result, the opening/closing timing of the intake valve **50** is adjusted. In this way, in the variable valve mechanism **100**, when the first link member **71** and the second link member **72** are swung in response to the engine rotation speed so that the intake side cam shaft **60** (the link flange **67**) and the cam sprocket **53** rotate relatively to each other, the opening/closing timing of the intake valve **50** can be changed.

In this way, in the variable valve mechanism **100** according to the embodiment, the first link member **71** and the second link member **72** swing to the outside of the cam sprocket **53** in the radial direction under a predetermined condition so that the intake side cam shaft **60** (the link flange **67**) rotates relatively to the cam sprocket **53**. For this reason, the phase in the rotation direction of the intake side cam shaft **60** can be changed in response to the swing operation of the link member **7** (the first link member **71** and the second link member **72**). Accordingly, an operating resistance can be suppressed to be low compared to a known configuration in which the centrifugal weight is sandwiched between the pair of driven members. As a result, the phase of the cam shaft **6** in the rotation direction can be smoothly changed.

Further, the first link member **71** includes the bolt **73** which is fixed to the cam sprocket **53** and serves as a swing shaft, the weight portion **71***b* which is disposed to be separated from the bolt **73**, and the engagement portion **71***c* which engages with the engagement pin **67***e* provided at the cam shaft **6** and transmits the rotation of the cam sprocket **53** to the cam shaft **6** and is supported by the cam sprocket **53** to be swingable. Here, in accordance with the rotation of the cam sprocket **53**, the weight portion **71***b* moves outward in the radial direction of the cam sprocket **53** and the engagement portion **71***c* moves to move the engagement pin **67***e*, thereby relatively rotating the intake side cam shaft **60**. The same applies to the second link member **72**. Accordingly, the intake side cam shaft **60** can be rotated relatively when the first link member **71** and the second link member **72** swung by the centrifugal force generated in accordance with the rotation of the cam sprocket **53** (in response to a change in rotation speed). For this reason, it is possible to smoothly change the phase in the rotation direction of the cam shaft **6** with a simple configuration without requiring a particular control mechanism for relatively rotating the intake side cam shaft **60**.

Further, since the first link member **71** and the second link member **72** are swung by the centrifugal force generated by the rotation of the cam sprocket **53**, a friction force of the bolt **73** can be reduced. For this reason, the weight portions **71***b* and **72***b* can be moved even when a change in torque of the engine **2** does not occur. As a result, it is possible to easily perform an inspection or an operation check of the cam shaft **6**.

Further, in the variable valve mechanism **100** according to the embodiment, the first link member **71** and the second link member **72** are disposed at the opposite side with the rotation axis of the cam sprocket **53** interposed therebetween and the first spring **74** and the second spring **75** are disposed at the opposite side with the rotation axis of the cam sprocket **53** interposed therebetween. Accordingly, the first link member **71** and the second link member **72** can be disposed with a good balance along with the first spring **74** and the second spring **75**. For this reason, the rotation of the cam shaft **6** can be smoothly kept without a weight portion for ensuring a balance.

In particular, the first link member **71** and the second link member **72** are disposed to be point-symmetrical to each other with respect to the center C of the rotation axis of the cam sprocket **53**. For this reason, a rotation force generated from the cam sprocket **53** can be symmetrically transmitted to the cam shaft **6** through the link members **7**. Accordingly, the rotation of the cam shaft **6** can be smoothly performed. Further, the rotation of the cam shaft **6** can be smoothly kept without a weight portion for ensuring a balance.

Further, the engagement grooves **71***d* and **72***d* are provided at the engagement portions **71***c* and **72***c* of the first link member **71** and the second link member **72**. The first holding position **711** and the second holding position **712** are respectively provided in the engagement grooves **71***d* and **72***d* and the first stopper portion **713***a* which protrudes toward the facing inner wall surface **714** is provided in the inner wall surface **713** disposed at a farther side from the bolt **73** in the inner wall surfaces of the engagement grooves **71***d* and **72**d. For this reason, the engagement pin **67***e* received in the first holding position **711** cannot move easily. Accordingly, even when a driving reaction force which is given from the intake valve **50** (the exhaust valve **51**) to the intake cam **62** (the exhaust cam **63**) is transmitted to the first link member **71** and the second link member **72** through the cam shaft **6** and the engagement portions **71***c* and **72***c*, the vibration of the first link member **71** and the second link member **72** can be suppressed.

Similarly, the second stopper portion **714***a* which protrudes toward the facing inner wall surface **713** is provided in the inner wall surface **714** disposed at a close side from the bolt **73** in the inner wall surfaces of the engagement grooves **71***d* and **72***d*. For this reason, the engagement pin **67***e* received in the second holding position **712** cannot move easily. Accordingly, even when a driving reaction force given from the intake valve **50** (the exhaust valve **51**) to the intake cam **62** (the exhaust cam **63**) is transmitted to the first link member **71** and the second link member **72** through the cam shaft **6** and the engagement portions **71***c* and **72***c*, the vibration of the first link member **71** and the second link member **72** can be suppressed.

Further, the engagement grooves **71***d* and **72***d* are provided with a substantially S-shaped moving line in which the center of the engagement pin **67***e* bypasses the first stopper portion **713***a* and bypasses the second stopper portion **714***a*. For this reason, it is possible to prevent the engagement pin **67***e* received in the first holding position **711** or the second holding position **712** from moving easily compared to a case where the moving line of the engagement pin **67***e* is linear. Accordingly, the first link member **71** and the second link member **72** can be swung and the first link member **71** and the second link member **72** can be returned to the non-swing state at a desired timing.

Here, a positional relation of the components of the link member **7** of the variable valve mechanism **100** according to the embodiment will be described with reference to FIG. **10**. FIG. **10** is a diagram illustrating a positional relation of components of the link member **7** of the variable valve mechanism **100** according to the embodiment. The components of the first link member **71** and the components of the second link member **72** have the same positional relation. In the following description, a description will be made by using the first link member **71** and a detailed description of the second link member **72** will be omitted. Additionally, for convenience of the description, the second spring **75** is not illustrated in FIG. **10**.

As illustrated in FIG. **10**, the first link member **71** is formed so that a distance L**1** of an imaginary line LA connecting a center C**1** of the bolt **73** forming a swing shaft to a center C**2** of the engagement pin **67***e* received in the first holding position **711** in the non-swing state is smaller than a distance L**2** of an imaginary line LB connecting the center C**1** of the bolt **73** and a locking position C**3** of the first spring **74** with respect to the locking hole **71***e*.

In this way, since the distance L**1** between the bolt **73** and the engagement pin **67***e* is set to be smaller than the distance L**2** between the bolt **73** and the first spring **74**, a rotation moment Ma for swinging the first link member **71** can be suppressed to be small when a driving reaction force given from the intake valve **50** (the exhaust valve **51**) to the intake cam **62** (the exhaust cam **63**) is transmitted to the first link member **71** through the cam shaft **6**, the engagement pin **67**e, and the engagement portion **71**c. Accordingly, it is possible to prevent a problem in which the first link member **71** easily swings.

Here, a direction of the driving reaction force transmitted from the engagement pin **67***e* to the first link member **71** becomes a direction of a tangential line TL between a concentric circle and the cam shaft **6** passing through the center C**2** of the engagement pin **67***e*. Here, the rotation moment Ma is obtained by the following equation when a force given from the engagement pin **67***e* by the driving reaction force is denoted by "F" and an angle formed by the imaginary line LA connecting the center C**1** of the bolt **73** and the center C**2** of the engagement pin **67***e* in the non-swing state and the tangential line TL of the circle indicated by the dashed line, passing through the center C**2** of the engagement pin **67***e*, and using the rotation axis of the cam shaft **6** (the cam sprocket **53**) as the center C is denoted by "α".

$$\text{Rotation moment } Ma=F\sin\alpha\cdot L1$$

Further, the first link member **71** is formed so that the angle α is smaller than an angle β formed by the imaginary line LB connecting the center C**1** of the bolt **73** and the locking position C**3** of the first spring **74** and the center line LC of the first spring **74**.

In this way, since the angle α is set to be smaller than the angle β, the rotation moment Ma for swinging the first link member **71** can be suppressed to be smaller than the rotation moment Mb for pressing the first link member **71** by the first spring **74** and the second spring **75** when the driving reaction force given from the intake valve **50** (the exhaust valve **51**) to the intake cam **62** (the exhaust cam **63**) is transmitted to the first link member **71** through the cam shaft **6** and the engagement portion **71***c*. Accordingly, it is possible to prevent a problem in which the first link member **71** easily swings. Here, the rotation moment Mb is obtained by the following equation when the spring constants of the first spring **74** and the second spring **75** are denoted by "K" and the expansion lengths of the first spring **74** and the second spring **75** are denoted by "x".

$$\text{Rotation moment } Mb=K\cdot x\sin\beta\cdot L2$$

Further, the first link member **71** is disposed so that the imaginary line LA connecting the center C**1** of the bolt **73** and the center C**2** of the engagement pin **67***e* in the non-swing state intersects at a right angle to the imaginary line LD connecting the center C of the rotation axis of the cam shaft **6** (the cam sprocket **53**) and the center **02** of the engagement pin **67***e*.

Accordingly, the bolt **73** is disposed in the vicinity of the movement direction accompanied by the rotation of the cam shaft **6**, that is, the tangential direction in the non-swing state. For this reason, even when the driving reaction force given from the intake valve **50** (the exhaust valve **51**) to the intake cam **62** (the exhaust cam **63**) is transmitted to the first link member **71** through the cam shaft **6**, the engagement pin **67***e*, and the engagement portion **71***c*, the direction of the driving reaction force substantially overlaps the imaginary line LA. Accordingly, since the angle α becomes very small, the rotation moment Ma for swinging the first link member **71** can be suppressed to minimum and thus an unexpected swing of the first link member **71** can be effectively suppressed.

Further, the first link member **71** is disposed so that the angle β including the rotation axis of the cam sprocket **53** among the angles formed by the imaginary line LB connecting the center C**1** of the bolt **73** and the locking position C**3** of the first spring **74** and the center line LC of the first spring **74** in the non-swing state becomes an acute angle.

In this way, since the angle β which is narrowed in accordance with an increase in swing angle of the first link member **71** is set to an acute angle in advance, the rotation radius of the weight portion **71***b* can be increased in accordance with an increase in swing angle of the first link member **71** and thus the centrifugal force of the weight portion **71***b* can be increased in proportional to the rotation radius. Accordingly, since the urging force increases as the swing angle of the first link member **71** increases in accordance with an increase in rotation speed of the cam sprocket **53**, the first link member **71** can be immediately operated. Meanwhile, the first link member **71** can be returned to the non-swing state in accordance with a decrease in rotation speed of the cam sprocket **53**. As a result, it is possible to improve the responsiveness of the operation of the first link member **71** in response to the rotation speed of the cam sprocket **53**.

Further, the distance L**2** between the center C**1** of the bolt **73** of the first link member **71** and the locking position C**3** of the first spring **74** with respect to the locking hole **71***e* of the first link member **71** is set to be larger than a distance L**3** of an imaginary line LF connecting a center C**5** of the bolt **73** of the second link member **72** and a locking position C**4** of the first spring **74** with respect to the locking portion **72***f* of the second link member **72**. Further, a distance L**4** between the center C**5** of the bolt **73** of the second link member **72** and a locking position C**6** of the second spring **75** with respect to the locking hole **72***e* of the second link member **72** is set to be larger than a distance L**6** between the center C**1** of the bolt **73** of the first link member **71** and the locking position C**7** of the second spring **75** with respect to the locking portion **71***f* of the first link member **71**.

Accordingly, even in a structure of pulling the weight portions **71***b* and **72***b* and the engagement portions **71***c* and **72***c* of the first link member **71** and the second link member **72**, the rotation moment Mc of the weight portions **71***b* and **72***b* becomes larger than the rotation moment Md of the engagement portions **71***c* and **72***c* and thus the first link member **71** and the second link member **72** thereof can be urged in the non-swing direction. Accordingly, even when the locking positions of the first spring **74** and the second spring **75** are provided at the weight portions **71***b* and **72***b* and the engagement portions **71***c* and **72***c* in a narrow space, the phase in the rotation direction of the cam shaft **6** can be stably changed.

Here, the rotation moment Mc is expressed by the following equation when the spring constants of the first spring **74** and the second spring **75** are denoted by "K" and the expansion lengths of the first spring **74** and the second spring **75** are denoted by "x". Further, the rotation moment Md is obtained by the following equation when the spring constants of the first spring **74** and the second spring **75** are denoted by "K", the expansion lengths of the first spring **74** and the second spring **75** are denoted by "x", and the angle between the center line LC and the imaginary line LF is denoted by "r".

$$\text{Rotation moment } Mc=K\cdot x\sin\beta\cdot L2$$

$$\text{Rotation moment } Md=K\cdot x\sin\gamma\cdot L3$$

Regarding the first link member **71** and the second link member **72**, the weight portions **71***b* and **72***b* are disposed at one side and the engagement portions **71***c* and **72***c* are disposed at the other side in an imaginary line LE connecting the center C**1** of the bolt **73** and the center C of the rotation axis of the cam sprocket **53**. Then, one end of the first spring **74** is locked to the locking hole **71***e* at the side of the weight portion **71***b* of the first link member **71** and the other end thereof is locked to the locking portion **72***f* at the side of the engagement portion **72***c* of the second link member **72**. Meanwhile, one end of the second spring **75** is locked to the locking hole **72***e* at the side of the weight portion **72***b* of the second link member **72** and the other end thereof is locked to the locking portion **71***f* at the side of the engagement portion **71***c* of the first link member **71**.

That is, both the first spring **74** and the second spring **75** are respectively locked to the first link member **71** and the second link member **72**. For this reason, when one ends

(ends on the side of the weight portions **71***b* and **72***b*) of the first spring **74** and the second spring **75** are pulled outward in the radial direction of the cam sprocket **53**, the other ends (ends on the side of the engagement portions **72***c* and **71***c*) of the second spring **75** and the first spring **74** move inward in the radial direction of the cam sprocket **53**. Accordingly, since the expansion/contraction amounts of the first spring **74** and the second spring **75** can be decreased, a burden on the springs can be reduced.

Further, since both ends of the first spring **74** and the second spring **75** are locked to the first link member **71** and the second link member **72**, the first spring **74** and the second spring **75** are operated at the same time when the first link member **71** and the second link member **72** swing. For this reason, the first spring **74** and the second spring **75** do not interfere with each other. Accordingly, since the first link member **71** and the second link member **72** can be disposed at a close position, the variable valve mechanism **100** can have a simple and compact structure.

Additionally, the invention is not limited to the above-described embodiment and can be modified into various forms. In the above-described embodiment, the sizes or the shapes illustrated in the accompanying drawings are not limited thereto and can be appropriately changed without departing from the effect of the invention. In addition, an appropriately modification can be made without departing from the object of the invention.

For example, in the above-described embodiment, a case has been described in which the pair of link members **7** (the first link member **71** and the second link member **72**) are provided and the pair of first springs **74** and the second spring **75** are provided, but the invention is not limited to this configuration. For example, the number of link members or springs may be one or three or more on the condition that the phase of the rotation direction of the intake cam shaft **60** can be changed in accordance with the rotation of the cam sprocket **53**.

Further, in the above-described embodiment, a case has been described in which the first link member **71** and the second link member **72** are disposed to be point-symmetrical to each other with respect to the center C of the rotation axis of the cam sprocket **53**, but the invention is not limited to this configuration. The first link member **71** and the second link member **72** can be disposed at arbitrary positions on the condition that the phase of the rotation direction of the intake cam shaft **60** can be changed in accordance with the rotation of the cam sprocket **53**.

Further, in the above-described embodiment, the single cylinder engine **2** has been exemplified, but the invention is not limited to this configuration. For example, the valve train **5** (the variable valve mechanism **100**) according to the embodiment may be also applied to a multi-cylinder engine.

Further, in the above-described embodiment, the single cylinder engine has a so-called four valve type valve train in which each of the intake valve **50** and the exhaust valve **51** is provided at two positions so that four valves are provided in total, but the invention is not limited to this configuration. The number of the intake valves **50** and the exhaust valves **51** can be appropriately changed.

Further, in the above-described embodiment, a case in which the variable valve mechanism **100** is applied to the SOHC type valve train **5** has been described, but the invention is not limited to this configuration. For example, the variable valve mechanism **100** may be also applied to a double overhead camshaft (DOHC) type valve train.

Further, in the above-described embodiment, a configuration has been described in which one of engagement portions is formed as an engagement pin and the other thereof is formed as an engagement hole or a groove, but the invention is not limited to this configuration. For example, one of the engagement portions may be formed as an engagement hole or a groove and the other thereof may be formed as a protrusion such as an engagement pin.

Further, in the above-described embodiment, the variable valve mechanism **100** is used to adjust the opening/closing timing of the intake valve **50**, but the invention is not limited to this configuration. The variable valve mechanism **100** may be used to adjust the opening/closing timing of the exhaust valve **51**.

Further, in the above-described embodiment, a predetermined centrifugal force (an engine rotation speed) during the operation of the variable valve mechanism **100** (when the first link member **71** and the second link member **72** swing) can be appropriately changed in response to a desired valve timing.

INDUSTRIAL APPLICABILITY

As described above, the invention has an effect that a phase of a rotation direction of a cam shaft can be stably changed and is particularly useful for a variable valve mechanism applicable to a single overhead camshaft (SOHC) type valve train, an engine, and an automatic two-wheeled vehicle.

REFERENCE SIGNS LIST

1 automatic two-wheeled vehicle
2 engine
5 valve train
50 intake valve
51 exhaust valve
53 cam sprocket
6 cam shaft
60 intake cam shaft
61 exhaust cam shaft
62 intake cam (intake side cam)
63 exhaust cam (exhaust side cam)
66 sprocket flange
67 link flange
100 variable valve mechanism
7 link member
71 first link member
71*a*, **72***a* support portion
71*b*, **72***b* weight portion
71*c*, **72***c* engagement portion
71*d*, **72***d* engagement groove (groove)
711 first holding position
712 second holding position
713*a* first stopper portion
714*a* second stopper portion
72 second link member
73 bolt (swing shaft)
74 first spring (first urging member)
75 second spring (second urging member)

What is claimed is:

1. A variable valve mechanism which changes an opening/closing timing of an intake valve or an exhaust valve in response to an engine rotation speed, the variable valve mechanism comprising:

a cam sprocket which rotates in response to a rotation of a crank shaft;

a cam shaft which is integrated with any one of intake side and exhaust side cams and is provided to be rotatable relatively to the cam sprocket; and

a link member that engages with the cam sprocket and the cam shaft and transmits a rotation from the cam sprocket to the cam shaft, wherein

the link member is supported by the cam sprocket to be swingable and swings in response to a change in rotation speed of the cam sprocket to rotate the cam shaft relatively to the cam sprocket,

the link member includes:

a swing shaft which is fixed to the cam sprocket;

a weight portion which is disposed to be separated from the swing shaft; and

an engagement portion which engages with an engagement pin provided in the cam shaft and transmits a rotation of the cam sprocket to the cam shaft;

the link member is supported by the cam sprocket to be swingable; and

the weight portion moves outward in a radial direction of the cam sprocket and the engagement portion moves to move the engagement pin in accordance with the rotation of the cam sprocket so that the cam shaft rotates relatively to the cam sprocket;

the engagement portion is formed as a groove having an inner wall surface, and

the groove is provided with a first holding position which receives the engagement pin while the link member does not swing to a predetermined position or more and a second holding position which receives the engagement pin while the link member swings to a predetermined position or more,

a first stopper portion is provided in the inner wall surface disposed at a farther side from the swing shaft in a vicinity of the first holding position, and

the first stopper portion protrudes toward the inner wall surface facing the first stopper portion.

2. The variable valve mechanism according to claim **1**, further comprising:

a spring that is locked to the link member and urges the weight portion inward in the radial direction of the cam sprocket, wherein

in a non-swing state of the link member, a distance of an imaginary line connecting a center of the swing shaft and a center of the engagement pin is smaller than a distance of an imaginary line connecting the center of the swing shaft to a locking position of the spring on the link member.

3. The variable valve mechanism according to claim **2**, wherein

in the non-swing state of the link member, an angle α formed by the imaginary line connecting the center of the swing shaft and the center of the engagement pin and a tangential line of a circle using a rotation axis of the cam shaft as a center and passing through the center of the engagement pin is smaller than an angle β formed by a center line of the spring and the imaginary line connecting the center of the swing shaft and the locking position of the spring.

4. The variable valve mechanism according to claim **2**, wherein

the spring is disposed so that one end of the spring is locked to a position near the weight portion in relation to the swing shaft,

an angle β formed by a center line of the spring and an imaginary line passing through the locking position of the spring and the center of the swing shaft is an acute angle, and

the imaginary line and the center line forming the angle β interpose a rotation axis of the cam sprocket.

5. The variable valve mechanism according to claim **2**, wherein

the link member is a first link member and the variable valve mechanism further includes an identical second link member,

the first link member is disposed at one side of a rotation axis of the cam sprocket and the second link member is disposed at another side of the rotation axis of the cam sprocket so that the first link member and the second link member interpose the rotation axis of the cam sprocket,

the spring is a first spring and the variable valve mechanism further includes an identical second spring

the first spring is disposed at one side of the rotation axis of the cam sprocket and the second spring is disposed at another side of the rotation axis of the cam sprocket so that the first spring and the second spring interpose the rotation axis of the cam sprocket.

6. The variable valve mechanism according to claim **5**, wherein

the first link member and the second link member are disposed to be point-symmetrical to each other with respect to a center of the rotation axis of the cam sprocket and the first spring and the second spring are disposed to be point-symmetrical to each other with respect to the center of the rotation axis of the cam sprocket.

7. The variable valve mechanism according to claim **5**, wherein

in the first link member and the second link member, the weight portion is disposed at one side and the engagement portion is disposed at another side with respect to an imaginary line connecting the center of the swing shaft and the center of the rotation axis of the cam sprocket;

one end of the first spring is locked to a position near the weight portion in relation to the swing shaft of the first link member and another end of the first spring is locked to a position near the engagement portion in relation to the swing shaft of the second link member; and

one end of the second spring is locked to a position near the weight portion in relation to the swing shaft of the second link member and another end of the second spring is locked to a position near the engagement portion in relation to the swing shaft of the first link member.

8. The variable valve mechanism according to claim **7**, wherein

a distance between a locking position of the first spring at the position near the weight portion in the first link member and the center of the swing shaft of the first link member is larger than a distance between the locking position of the first spring at the position near of the engagement portion in the second link member and the center of the swing shaft of the second link member; and

a distance between a locking position of the second spring at the position near the weight portion in the second link member and the center of the swing shaft of the second link member is larger than a distance between the locking position of the second spring at the position near the engagement portion in the first link member and the center of the swing shaft of the first link member.

9. The variable valve mechanism according to claim **1**, wherein

in a non-swing state of the link member, an imaginary line connecting a center of the swing shaft to a center of the engagement pin intersects at a substantially right angle to an imaginary line connecting a center of a rotation axis of the cam shaft and the center of the engagement pin.

10. The variable valve mechanism according to claim **1**, wherein

a second stopper portion is provided in the inner wall surface disposed at a close side to the swing shaft in a vicinity of the second holding position, and

the second stopper portion protrudes toward the inner wall surface facing the second stopper portion .

11. The variable valve mechanism according to claim **10**, wherein the groove is provided with a substantially S-shaped moving line in which a center of the engagement pin in a front view bypasses the first stopper portion and the second stopper portion.

12. An engine comprising:

the variable valve mechanism according to claim **1**.

13. An automatic two-wheeled vehicle comprising:

the engine according to claim **12**.

* * * * *